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Bull Mountain Coal Field
Reclamation Plan

For: Abandoned Mine Reclamation Bureau
Montana Department of State Lands

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TABLE OF CONTENTS

Page

List of Tables, Map, Figure iii

INTRODUCTION/GOALS 1

STUDY METHODS 3
    Geotechnical 3
    Surface and Groundwater Hydrology 4
    Geology 4
    Preliminary Engineering 5
    Health and Safety Hazards 7
    Soils 8
    Vegetation and Land Use 9

STUDY AREA DESCRIPTION 11
    Geology 11
    Mineral Resources 17
    Water Resources 18
    Climate 25
    Vegetation/Land Use 25
    Soils 28

ENVIRONMENTAL IMPACTS 31
    Hydrology 32
    Site Specific Impacts 35

RECLAMATION PLAN 65
    Technologically Feasible Abatement Methods 65
    Site Specific Plans By Site 88

RANKING 102

REFERENCES 105

APPENDIX A - SOILS
APPENDIX B - WATER QUALITY ANALYSES
APPENDIX C - DRILL LOG DATA

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LIST OF TABLES, FIGURE, MAP

Page

TABLE A. Generalized stratigraphic section of the Bull Mountain area (revised from Zimmerman, 1956) 14

TABLE B. Plant species colonizing abandoned mine sites in the Bull Mountain Coal Field 36

TABLE C. Probability of future subsidence 69

TABLE D. Liming needs for Bull Mountain waste materials 73

TABLE E. Fertilization needs of materials at the Bull Mountain Coal Field 75

TABLE F. Standardized seedbed preparation for major materials of the Bull Mountain Coal Field 76

TABLE G. Cost to treat materials at the Bull Mountain Coal Field ... 78

TABLE H. Seed mixtures and planting rates for revegetation units ... 81

TABLE I. Revegetation cost estimates for the Bull Mountain Coal Field sites 85

TABLE J. Evaluation of health and safety hazards 104

FIGURE 1. Yearly temperature and precipitation pattern for the study area 26

MAP 1. Location of the 22 abandoned mine sites reviewed 12

INTRODUCTION/GOALS

A study was conducted of abandoned mine sites in the Bull Mountain Coal Field for the Montana Department of State Lands, Abandoned Mine Reclamation Program. Objectives and goals for this project are found in Montana's Permanent Program Strip and Underground Mine Reclamation Rules and Regulations. Specifically ARM 26.4.1235(3) states that reclamation efforts in identified abandoned mine areas should result in certain benefits as follows:

(a) protection of human life, health, or safety;
(b) protection of the environment, including air and water quality, abatement of erosion and sedimentation, fish, wildlife and plant habitat, visual beauty, historic or cultural resources, and recreation resources;
(c) protection of public or private property;
(d) abatement of adverse social and economic impacts of past coal mining on persons or property including employment, income and land values or uses, or assistance to persons disabled, displaced, or dislocated by past mining practices;
(e) improvement of environmental conditions which may be considered to generally enhance the quality of human life;
(f) improvement of the use of natural resources, including post-reclamation land uses which:
    (i) increase the productive capability of the land to be reclaimed;
    (ii) enhance the use of surrounding lands consistent with existing land use plans;
    (iii) provide for construction or enhancement of public facilities;
    (iv) provide for residential, commercial, or industrial developments consistent with the needs and plans of the community in which the site is located;
(g) demonstrate to the public and industry methods and technologies which can be used to reclaim areas disturbed by mining.

Additional considerations outlined in Montana regulations include

economic costs and efficiencies of reclamation.

The baseline studies and reclamation plan for the Bull Mountain Coal Field abandoned mine sites were completed by OEA Research with subcontract assistance from David Stiller and Associates, Delta Engineering, and GMT, Inc. Both OEA Research and David Stiller and Associates are located in Helena, Montana. Delta Engineering and GMT, Inc. have offices in Great Falls, Montana.

Baseline studies were conducted to determine existing conditions at each site. These data were used to describe abandoned mine impacts and to develop a reclamation plan for each site. Geology, hydrology, water quality, soils, vegetation, and land use were evaluated. Results of these investigations were integrated with a literature review of reclamation technologies in order to propose reclamation procedures appropriate to the respective environmental problem(s) present at each site.

Reclamation priorities for each site were based on several factors: health and human safety, extent and severity of disturbance, efficiency of pollution abatement, benefits to the environment, and economics of each abatement strategy to accomplish the necessary control. In each case evaluated, the combined input from all disciplines contributed to a ranking of sites as to severity and degree of mitigation necessary. From this analysis, a preferred reclamation option was recommended. Finally, a ranking based on the degree of human and environmental hazards was made for all sites relative to one another to identify a sequence of reclamation actions for the entire study area.

STUDY METHODS

GEOTECHNICAL STUDIES

The geotechnical portion of the study utilized a number of investigative methods. Methods included literature searches, office visits with various agencies, several visits to each site, research of in-house files, contacts with contractors and mine owners, a field drilling program, evaluation of the acquired data, engineering analyses, and formulation of reclamation plans.

Literature searches were conducted from such sources as the Department of State Lands (DSL), Office of Surface Mining (OSM), Montana College of Mineral Science and Technology, Massachusetts Institute of Technology, U.S. Geological Survey (USGS), and Burlington Northern (BN). Useful information was retained for the project file.

Office visits, usually in connection with the literature search, were utilized to obtain unpublished or personal knowledge. The process yielded little additional information.

During site visits surface features were mapped, literature checked, and owners contacted. Formulation of reclamation alternatives began at this point. Owner contacts did not provide much additional information.

Contractors familiar with reclamation alternatives considered feasible for the study areas were contacted. The purpose was to evaluate their experience in similar situations. The contacts appear to have been very worthwhile, in that several unpublished OSM studies were identified.

A field drilling program was conducted at the Republic #3 site. Its purpose was to assess thickness of slack within the Gebhardt Post Yard, the site of two previous burns, and a slack pile near the sealed entrance to the Republic Mine. Temperatures within the slack were

measured. One additional boring was drilled in the post yard at the request of Mr. Gebhardt. He expressed concern about a "hot spot" under a slab pile.

The accumulated data were evaluated for applicability, accuracy, and pertinence to the project. Data were shared with the other project personnel and discussed in detail during site visits. From the evaluation and discussions, a final set of reclamation and abatement recommendations were developed.

SURFACE AND GROUND WATER HYDROLOGY

Surface and ground water hydrology were evaluated through an extensive literature search complimented by on-ground investigations to gain information at individual mine sites.

The following agencies were contacted regarding hydrologic information in the Bull Mountain area: USGS, Montana Water Quality Bureau (MWQB), DSL, Montana Department of Natural Resources and Conservation (MDNRC), City of Roundup, Montana Bureau of Mines and Geology (MBMG), Musselshell County Soil Conservation Service (SCS), Montana State Library, and U.S. Mine Safety and Health Administration. Several landowners in the area also offered information regarding water level and quality in the mine workings.

A field investigation was conducted to ascertain hydrologic characteristics of the study area's mine sites. Included in the investigation was an evaluation of potentially affected surface water regimes due to abandoned mines; an inventory of stock and domestic wells in the proximity of the abandoned mines; an analysis of discharging mine adits; and an evaluation of the potential for future water-related problems associated with designated abandoned mines.

GEOLOGY

The geology of the study area was evaluated by researching pertinent

literature, in addition to field mapping of appropriate mine sites. The literature search was conducted to assess the regional geologic characteristics of the study area, as well as to gain an understanding of the area's mining history and mineral resources. Geologic mapping was completed at selected mine sites to ascertain geologic characteristics significant to reclamation planning.

The following agencies were contacted for information concerning Bull Mountain geology, mineral resources, and mining history: USGS, MBMG, DSL, U.S. Bureau of Land Management (USBLM), Montana State Library, Musselshell County SCS, and U.S. Mine Safety and Health Administration. In addition, interviews with numerous local residents provided valuable information and data.

Detailed geologic field investigations were completed at mine sites suspected to be of high priority relative to public health and safety. These field investigations entailed standard geologic mapping techniques, including traverses to delineate stratigraphy, structure, and surficial features. The mapping effort was concentrated around mine openings, as well as in the direction of underground mining. In this fashion, geologic data were gathered which were used in planning reclamation strategies.

PRELIMINARY ENGINEERING

Preliminary engineering analysis was undertaken through a series of interrelated studies and investigations intended to identify general and specific impacts and hazards associated with abandoned coal mines in the Bull Mountain Coal Field. Mine sites investigated were prescribed by DSL, Abandoned Mine Reclamation Bureau (AMR). Several additional mine sites not listed by DSL for this study were also investigated for impacts and potential abatement alternatives. Engineering considerations for the preliminary study consisted of assembling and summarizing all available information; identifying the safety hazards and the physcial impacts which can be abated or remedied using technical methodologies; assessing the severity of the impacts and hazards; and a

preliminary estimate of costs for the selected abatement and reclamation alternatives.

Information collected for the preliminary engineering study included USGS quadrangle maps of the areas in which the mine sites are located and a personal visit and inspection of the sites to view and identify impacts. Several photographs were taken at each site for later evaluation and review.

Following the initial on-site inspection, assembly of available information was continued, with efforts made to collect as much data as possible. Sources of information included the DSL, USBLM, MBMG, BN, individual landowners, and various other reports. Aerial photos, topographic maps, archive maps of old workings, mine site inventories, site photos, and landowner recommendations were compiled and evaluated.

The information collected was summarized for each site in the study area. Summaries included location of the site by township, range, section, and quarter section, together with the distance from either Roundup or Melstone by road; identification of impacts to public safety and health; assessment of the relative severity of impacts identified; recommendations for abatement of impacts, and preliminary estimates of costs of reclamation or remedial action.

Preliminary cost estimates for reclamation of physical hazards to health and safety considered in the civil engineering analysis were developed on a site-specific basis. Since the requirements for reclamation vary greatly from site to site, it was felt that trying to generalize cost data for specific items at all sites was not appropriate. Some of the sites are amenable to contracts detailing specific bid items, but most sites appear to be better bid as lump sum contracts. Material quantities and types vary greatly from site to site, as do the impacted areas and scope of work required. Also, some sites may require specialized methodologies which will only be applicable to that particular site.

The preliminary cost estimates were compiled using methodologies or

equipment compatible with our recommendations for reclamation at the particular site. Equipment rental rates, together with labor costs, including overhead and profit, were used as were estimated costs for items on a unit-price basis where appropriate. Sources of data for estimating purposes included discussions with contractors engaged in similar work, average costs from past reclamation projects, bid tabulations provided by DSL, experience of Delta Engineering personnel, and published cost guides such as Means Construction Cost Data and the equipment rental rate "Blue Book".

An integral part of the preliminary engineering analysis was a second on-site inspection of the sites. The second site review was attended by all members of the study team, together with DSL personnel. On-the-spot review of impacts and discussion of recommended or preferred techniques and alternatives for abatements were prescribed by the study team and the DSL representative. The results and data collected from the second site visit were incorporated with all previously collected data to establish the preliminary engineering alternatives.

HEALTH AND SAFETY HAZARDS

A major objective of this study was to locate and document the extent and severity of impacts, both imminent and potential to the health and safety of persons and livestock. The civil engineering portion of this investigation concentrated mainly on the physical problems which exist or could develop as a result of past mining activity and the selection of construction alternatives to correct or mitigate these problems. Impacts of mine fires or burning, future subsidence, and embankment stability are contained and described in the geotechnical portion of this investigation.

Physical impacts considered in the civil engineering analysis include open portals and adits, open or uncovered shafts, ground subsidence; and hazardous structures such as tipples, loading ramps, potential fire hazards from slack coal, erosion problems associated with toxic or infertile spoil and waste piles, trash and debris scattered around the

sites, and aesthetic degradation.

Health and safety hazards were evaluated and ranked depending upon severity and immediate danger to health and/or safety, location and accessibility, and proximity of the hazards to residential or inhabited areas. Abatement of hazards located near populated areas, agricultural sites, or main thoroughfares is of higher priority than those located in remote, isolated, or relatively inaccessable or uninhabited areas.

SOILS

A review of literature was used to identify existing knowledge of soils, mine wastes, and the environment to which they are exposed. Observations of waste materials at all identified mine sites were made to determine stability, toxicity, fertility, and in general, suitability as a medium for plant growth. Species composition and vigor of plants on waste piles and signs of erosion or their physical problems were also noted. Reaction (pH) of unvegetated materials was taken to indicate potential for chemical problems.

Sites were selected representing: 1) the most common types of waste materials; 2) the most visible types of problems, and 3) the range of possible types of problems. Soil samples were taken from the upper one foot in most cases, but on occasion were also taken from the upper two to four feet if wastes had the potential for being used as a planting medium. Samples of surface, subsurface, and substrate materials were taken from soils at the Roundup Mine area where treatment of subsidence might require the use of soil material for fill.

Laboratory analyses included fertility and toxicity related parameters used to rate topsoil suitability. Particle size determination using the hydrometer method gave very fine sand, sand, silt, and clay percentages. Water holding capacity was measured on selected samples at 1/3 and 15 bar with a pressure membrane apparatus. Saturation percentage was also measured. Organic matter, pH, electrical conductivity, extractable cations and sodium adsorption ratios were

measured routinely. Samples from a range of material types were chosen for fertility tests including nitrate-nitrogen, available phosphorus, extractable potassium. Boron, molybdenum and selenium were measured at several sites where toxicity from those elements was suspected. Three samples with low pH had an acid-base analysis done to give a more accurate lime requirement. Data is recorded in Tables 1 through 3 (Appendix A).

The first stage of reclamation analysis is to see if the materials are fertile, nontoxic, and provide a suitable medium for growth. Suspect levels of toxic elements were used to rate topsoil or subsoil suitability (Appendix A). Soil fertility ratings were based on current research in similar soils and settings such as other semi-arid grasslands of the northern Great Plains (Berg, 1980; Willmuth and DePuit, 1977; Woodmansee, et al., 1978). Soil water holding capacity in combination with climatic factors affecting water availability was analyzed to determine the reclamation potential based on climate (Toy and Munson, 1978). The stability of the site as it relates to erosion potential was also considered in determining suitability for seedling establishment. The potential for fire in slack coal piles was considered because of the hazard to people and property as well as the effects to the material as a medium for plant growth.

Treatment alternatives are based on current methods that are technically relevant and economically feasible at Bull Mountain.

VEGETATION AND LAND USE

Vegetation resources and land use in the study area were evaluated through on-the-ground field reconnaissance and discussions with local land owners. Native vegetation adjacent to disturbed abandoned mine sites was habitat typed using the technique developed by Mueggler and Stewart (1980), Pfister, et al. (1977) and Jorgenson (1979). Vegetation colonizing disturbed sites was identified using standard taxonomic manuals for the area. Information on adjacent undisturbed land, the abandoned mine sites, and surrounding land use values provided insight

into preparation of seeding mixtures and techniques for reclamation. Conversations with land owners also contributed to formulation of appropriate reclamation techniques.

Other biological resources present in the study area were evaluated during reconnaissance. Evidence of wildlife and wildlife values for abandoned mine sites was determined. An aquatic biological investigation of creeks in the area was unnecessary due to the lack of AMR impacts to those few creeks with perennial flows.

Delineation of features significant to reclamation planning was accomplished through aerial photo interpretation, a review of appropriate literature, and field mapping. Air photos of individual mine sites were evaluated as to outstanding and unique features which could potentially effect human health and safety. Subsequent to this evaluation, the mine sites were field truthed to verify features delineated on the air photos. During field evaluations, pertinent features were more accurately located on the air photos.

A literature search was conducted for available published information and maps relative to the study area, and potential effects on human health and safety. These data were evaluated in the field and, if appropriate, incorporated onto the air photo site maps. All mapping completed on air photos will be transferred to the appropriate topographic maps when these maps are made available.

STUDY AREA DESCRIPTION

The abandoned mine lands of concern to the Department are located in the Bull Mountain Coal Field, which is contained primarily in Musselshell, Yellowstone, and Golden Valley Counties. Significant mining commenced in 1907 and continued until 1956. At its peak, major mines in the region produced over 400,000 tons per year.

Twenty-two abandoned mine sites were identified for review (Map 1). The majority of these sites lie in the vicinity of Roundup and Melstone, Montana, the two principal towns within the study area. The location of these sites near populated areas poses possible health and safety hazards to local residents.

GEOLOGY

The geology of the Bull Mountain area has been discussed wholly or partly by the following investigators: Richards (1910), Stone and Calvert (1910), Woolsey and others (1917), Bowen (1918), Ellis and Meinzer (1924), Reeves (1926), Zimmerman (1956), Conner and Griffth (1980), and Stoner and Lewis (1980). The majority of the literature relative to the Bull Mountain area concerns oil and gas prospects, coal resources, or ground water resource potential.

The Bull Mountain area geology is dominated by the Fort Union Formation of Paleocene age. The Hell Creek Formation, Fox Hills Formation, and Bearpaw Shale, all of upper Cretaceous age, subcrop to the Fort Union Formation in the region and outcrop periphreal to the Bull Mountains area. The structure of the Bull Mountains is controlled by a broad synclinal basin which occupies the entire area, flattening to nearly horizontal to the east and south and extending to the north and northwest as two sharply accentuated folds (Woolsey and others, 1917). Minor folds within the basin are common, and they occasionally expose the Hell Creek and Fox Hills Formations and the Bearpaw Shale at the surface. No major fault systems are present in the Bull Mountain area.

MAP 1. Location of the 22 abandoned mine sites reviewed.

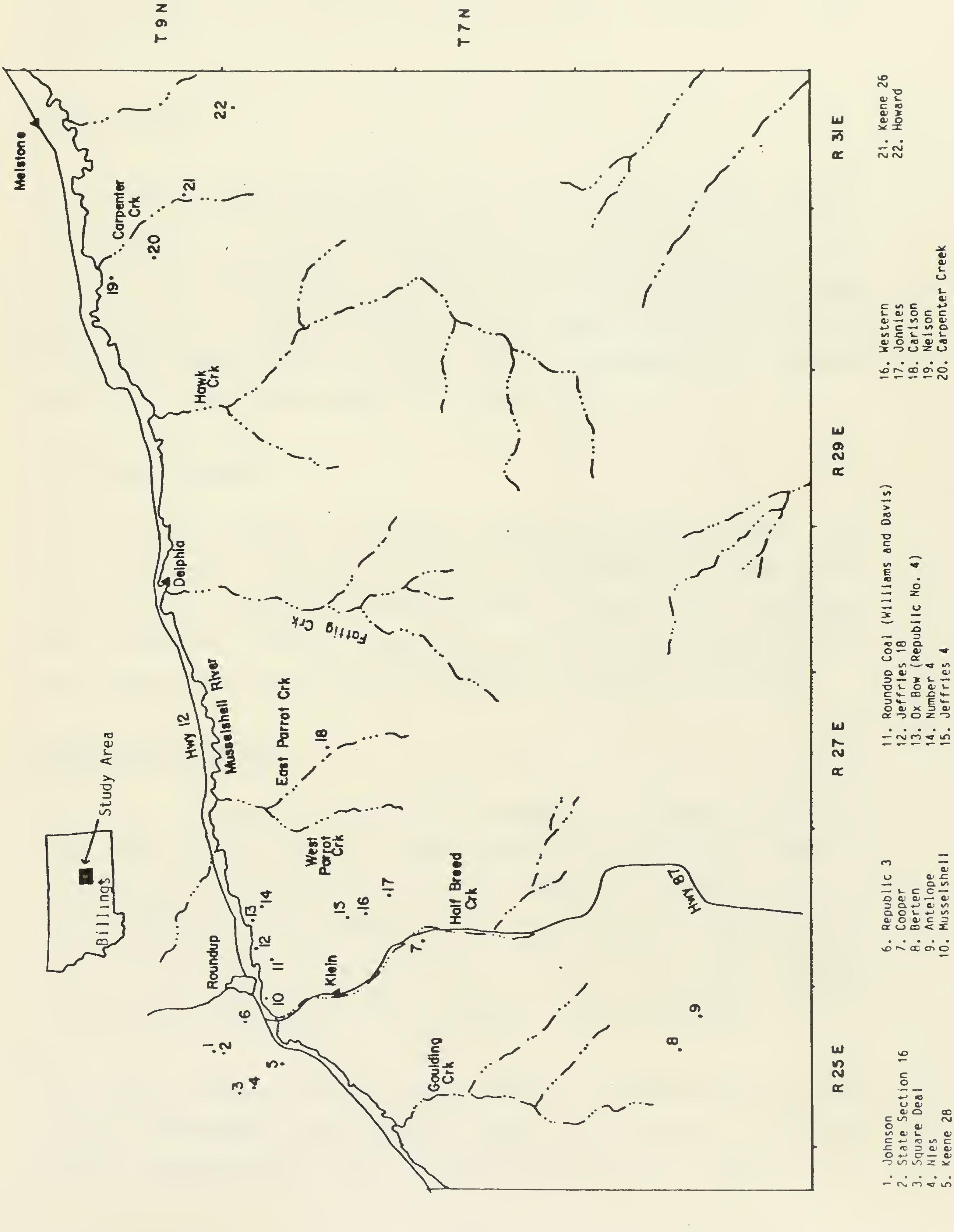


Table A presents a generalized stratigraphic section of the Bull Mountain area. The following presents a brief description of the stratigraphic units exposed in the area which are germane to this study.

Bearpaw Shale

The Bearpaw Shale is comprised of dark gray, marine shale of upper Cretaceous age. The unit contains numerous calcareous concretions and is abundantly fossiliferous. It represents the lowest stratigraphic unit outcropping in the Bull Mountains with thicknesses approximating 1,000 feet (Zimmerman, 1956). These shales rest conformably on the Cretaceous Judith River Formation. The unit weathers into rounded slopes and tends to form adobe soil (Bowen, 1918).

Fox Hills Formation

The Fox Hills Formation conformably overlies the Bearpaw Shale. The unit is of upper Cretaceous age and is approximately 400 feet thick. The Fox Hills consists of alternating beds of gray to tan sandstone, shale, claystone, and thin coal beds near the top. The unit thins from west to east across the Bull Mountains to about 200 feet thick.

Hell Creek Formation

The upper Cretaceous Hell Creek Formation conformably overlies the Fox Hills Formation. The lower portion of the Hell Creek is stratigraphically similar to the Fox Hills; that is, it consists of tan to buff sandstones interbedded with thin lenses of shale and siltstone. The sandstone units of the upper Hell Creek contain a higher fraction of silt than those contained in the Fox Hills Formation, and this characteristic defines their contact (MBMG, unpublished data).

The upper portion of the Hell Creek consists of yellowish-gray silty and clayey carbonaceous and bentonitic shale and siltstone. At specific locales, yellowish-gray, fine- to medium-grained silty sandstone and

TABLE A. Generalized stratigraphic Section of the Bull Mountain Area (revised from Zimmerman, 1956).

System	Series	Formation		Approx. max. thickness (feet)	Lithologic character
Quaternary	Recent	Alluvium and lake deposits		40	Unconsolidated gravel, sand, silt, and clay.
	Pleistocene	Terrace deposits		80	Well-sorted, unconsolidated sand and gravel deposits.
Tertiary	Pliocene Miocene (?)				
	Paleocene	Fort Union formation	Tongue River member	1600	Lenticular beds of massive, resistant buff and gray sandstone interbedded with shale, clay, and coal.
			Lebo Shale member	250	Olive-green, gray, and tan sandy shale; contains thin beds of arkosic sandstone and some coal.
			Tullock member	350	Interbedded light-gray shale, light-gray fine-grained sandstone and siltstone, and thin but persistent coal beds.
Cretaceous	Upper Cretaceous	Hell Creek Formation		650	Tan to buff sandstones interbedded with gray to light-gray shale and siltstone. Basal contact is gradational.
		Fox Hills Formation		400	Gray to tan sandstone, shale, claystone. Thin beds of coal in upper part.
		Colorado shale		2200	Predominantly dark blue to black marine shale; contains beds of bentonite, concretions, and some sandstone.
	Lower Cretaceous	Kootenai formation		400	Red sandstone, siltstone, and shale; contains several gray to brown sandstone beds.
Jurassic	Upper Jurassic	Morrison formation		220	Varicolored shale, mudstone, siltstone, and sandstone; contains a few thin beds of nodular limestone.
		Ellis group	Swift formation	120	Principally glauconitic marine sandstone and shale.
			Rierdon formation	79	Gray shale containing fossil belemnites and oysters; contains a few thin limestone beds near the base.
	Middle Jurassic		Piper formation	220	Principally limestone and shale; contains several beds of gypsum and a little sandstone.
Pennsylvanian and Mississippian		Amsden formation			Gray limestone that weathers red, dolomite, red siltstone, and clay.

thin coal beds are present. These beds are laterally discontinuous as a result of continental deposition (Reeves, 1927).

Fort Union Formation

The Bull Mountain area is dominated by the Tertiary Fort Union Formation. Three members have been identified in the Fort Union in this area. The members are, in ascending order, the Tullock Member, the Lebo Shale Member, and the Tongue River Member. The Tullock Member is comprised of 200 to 350 feet of interbedded light gray shale, light gray, fine-grained sandstone and siltstone, and thin but laterally persistent coal seams. The Tullock, when exposed in outcrop, forms a series of steep parallel hogbacks separated by narrow valleys due to a southern dip in the northern portion of the Bull Mountains, and it creates steep scarps in the southern and western portion of the region due to the flatness of the beds in this area (Woolsey and others, 1917).

The Lebo Shale Member consists of olive-green, yellow, brown, and black sandy clay, sandy shale, and soft arkosic sandstone. The Lebo Shale is 200 to 300 feet thick and contains two carbonaceous zones, the most prominent of which is known as the Big Dirty bed. The unit is notable for its lack of resistance to erosion which tends to produce wide valleys bounded by sandstone ridges. Andesitic material within the unit has been correlated with a source in the Livingston Group located west of the Bull Mountains (Stone and Calvert, 1910).

The upper member of the Fort Union Formation, exposed throughout the area, is the Tongue River Member. This unit is composed of light buff to whitish-gray sandstone in beds ranging in thickness from less than a foot to over 50 feet, interbedded with claystone, shale, and numerous beds of coal. Most of the sandstone is massive but locally it exhibits fine laminations. The sandstone typically weathers to smooth, rounded faces and locally assumes "toad-stool" forms. At the base of the sandstone, an irregular conglomerate commonly is present (Woolsey and others, 1917). The conglomerate consists of yellow and gray clay and shale pebbles set in a matrix of yellowish-brown impure coarse-grained

sandstone, ranging in thickness from one to five feet. The basal conglomerate is laterally persistent. The interbeds are gray, light green, or yellow, clayey, soft shale which grade into a shaley sandstone.

At least 26 coal seams are present within the Tongue River Member ranging in thickness from one to 15 feet (Woolsey and others, 1917). The coal seams are separated by interburden intervals of 50 feet or less in the western portion of the Bull Mountains and by 100 feet or more in the eastern part of the region.

Terrace Gravels

Flat areas adjacent to and above the present Musselshell River floodplain are indicative of floodplain remnants when the river was 75 to 175 feet higher than at present. These flat areas, probably developed during Tertiary time, are exposed intermittently along the Musselshell River throughout its length. The terrace remnants are comprised of poorly sorted, subrounded gravels which occasionally exhibit stratification and imbrication in good exposures. Many of the smaller fragments in the gravel matrix are composed of igneous rocks probably derived from either the Crazy Mountains or the Big Snowy Mountains located west of the study area (Ellis and Meinzer, 1924).

Alluvium

Alluvial deposits of Quaternary age have developed along major drainageways in the Bull Mountain region. Specifically, the Mussellshell River, Fattig Creek, and East and West Parrot Creeks (Map 1) have developed recognizable and persistent floodplains and associated alluvial systems. The alluvium is typically comprised of basal gravel overlain by a finer fraction of silt and clay. The basal gravel is generally smaller in size and more poorly sorted than are the terrace gravels previously described. Maximum thickness of the unconsolidated alluvial material along the Musselshell River is about 35 feet. Alluvium of valleys and streams tributary to the Musselshell River generally is

thinner, contains more silt, and has a lower permeability than that in the Musselshell Valley (Zimmerman, 1956). Many of the larger producing wells in the area obtain water from these alluvial systems.

MINERAL RESOURCES

Coal is by far the most important mineral resource in the Bull Mountains. Oil and gas exploration has historically been sporadic in the area, and the potential for development appears minimal. Other resources that possibly could be utilized in the area include shale, clay, and foundation materials. Development of any of the area's resources obviously depends on economic conditions and mineral demands.

All coal in the Bull Mountain Field is classed as subbituminous. The coal beds vary laterally in thickness and many seams pinch-out completely and reestablish themselves within a short distance. Most of the coal strata in the region are contained in the Tongue River Member of the Fort Union Formation. The 26 coal beds mapped by Woolsey and others (1917) fall into two main groups separated by 190 to 300 feet of interburden. The coal in the upper group is readily visible in most places owing to the rapid erosion of the sandstone interburden and steep scarps that subsequently form. The beds of the lower coal group are more difficult to discern in a surficial expression as the seams generally underlie the broad valleys and low rolling hills common to the area.

Commercial mining of coal resources in the Bull Mountains began on the Roundup bed in the northwestern portion of the field in 1907. At the same time, mining of the Carpenter bed was initiated on a commercial scale in the northeast portion of the field (Richards, 1910). Coal development flourished in the teens and twenties as a result of the need to provide coal for steam- powered locomotives of the Chicago, Milwaukee, and St. Paul Railway. Coal production continued to be important in the area until the late 1950's when demand for coal by the railroads diminished. Many of the major mines in the area typically

produced over 400,000 tons/year during this period. Recent coal production has come from surface mines operated by P & M and Divide Mining Companies. Louisiana Land and Exploration performed exploration and some preliminary baseline data collection for a proposed underground coal mine south of Roundup, but dropped its permits in 1982. Recent interest has concentrated on mining the Mammoth coal seam which outcrops on the south side of the Bull Mountains.

The recent slide in the coal market has decreased interest in large-scale coal development in the region. In addition, competition from surface mines in the Powder River Basin of Montana and Wyoming paints a rather bleak picture for near-future coal development in the Bull Mountains.

WATER RESOURCES

Surface Water

The primary surface water feature in the Bull Mountain study area is the Musselshell River, which bounds the northern extent of the mountains (Map 1). Other principal surface water features in the study area include major tributaries to the Musselshell River. These tributaries include Fattig Creek, Rehder Coulee, Halfbreed Creek, East Parrot Creek, and West Parrot Creek. Streams in the area are heavily used for irrigation, stock watering, and occasionally for domestic use.

The Musselshell River originates at the confluence of its North and South Forks about 80 miles west of Roundup. The river flows approximately 100 miles east and north of Roundup before emptying into the Missouri River. The river valley is typically less than one mile wide, with irrigation activities prominent in the bottomland. Water withdrawals and subsurface return flow are common along the Musselshell's course.

The surface water features in the Bull Mountains listed above all drain northward to the Musselshell River. The largest of these tributaries is

Halfbreed Creek, which flows perennially for about two to three miles above its mouth. Numerous irrigation and stock impoundments are present along Halfbreed Creek, many of which have been breached.

Rehder Coulee, a tributary to Halfbreed Creek, is an ephemeral stream flowing in response to snowmelt and/or intense precipitation events. Green grasses in the channel during late summer and the presence of riparian vegetation along its course indicate that subsurface water lies near the surface in sections between the mouth and about two miles upstream (Knapton, 1982).

Parrot Creek splits about two miles upstream from its mouth, forming West and East Parrot Creeks. In both forks, perennial flow is observed in upstream and downstream reaches, with mid-stream reaches generally being dry. Apparently, the constant-flow portions of the streams are sustained by springs. Several earthen dams have been constructed on both drainages for agricultural use.

Fattig Creek has a drainage area approximately the same size as that of Halfbreed Creek. The stream has sustained flow in several reaches owing to alluvial springs scattered along the drainage. Earthen impoundments are also common in this drainage.

Surface Water Flow Characteristics

Flow characteristics of the Musselshell River and Halfbreed Creek have been analyzed by Knapton (1982). Streamflow data indicate that baseflow is the dominant component of flow during the year, provided any flow is present. The typical base flow regime is interrupted by direct runoff input as a result of snowmelt, usually beginning in March, and as a result of summer and early fall precipitation events (Knapton, 1982).

Irrigation practices exert a strong influence on the flow regimes of all the major surface water systems in the Bull Mountains area. Many of the smaller streams in the Bull Mountains have their entire flow

diverted for irrigation purposes. Flow patterns of Bull Mountains streams are, therefore, dictated by agricultural practices during the irrigation season.

Mean annual discharge for the Musselshell River near Roundup (1947-1979) is 228 cfs (Knapton, 1982). Average monthly maximum is 608 cfs and average monthly minimum is 49 cfs. Approximately 27 percent of direct runoff occurs in June when average monthly flow is at a maximum of 4,320 cfs. The winter months typically produce the smallest discharges, while larger flows are recorded, on the average, during March, May, June, and July.

Halfbreed Creek has a generally similar flow regime to that of the Musselshell River, although actual flow values are much smaller. Typical hydrographs for Halfbreed Creek show extended flows following major snowmelt with a gradual decline in flow into summer (Knapton, 1982). Fluctuations in streamflow are of a much shorter duration than those in the Musselshell River owing to the smaller drainage area of Halfbreed Creek. Maximum discharge recorded at the USGS gaging station on Halfbreed Creek (period of record-1977 to 1979) was 345 cfs, and minimum flow was 0.35 cfs (USGS, 1979). Average annual flow is approximately 2.5 cfs.

The remainder of the streams in the Bull Mountains are ungaged, and no flow data exist. The streams probably have similar characteristics to those of Halfbreed Creek, and flow patterns are expected to be similar, although of different magnitudes.

Surface Water Quality

Rioux and Dodge (1980) compiled water quality data for streams in the Bull Mountains area. Results of their investigation indicate TDS concentrations for streams in the Bull Mountains range from 800 milligrams/liter (mg/l) to about 1300 mg/l. An exception to this range is Fattig Creek where a maximum TDS of 2100 mg/l was recorded. TDS concentrations in the Musselshell River range from about 450 to 1800

mg/l, with the lowest concentrations occurring during highest stage.

The major cations in Bull Mountains' surface water include calcium, magnesium, and sodium. Of the anions, bicarbonate and sulfate occur in greatest concentrations (Rioux and Dodge, 1980). The chemical character of the Bull Mountains streams indicate little variability throughout the annual flow cycle in comparison to many streams of eastern Montana (Knapton, 1982). The Musselshell River, on the other hand, exhibits large variability in both TDS and the chemical character of the water during the annual flow cycle. The baseflow water quality of the Musselshell River is generally a sodium-sulfate type, while during runoff periods, the water is typically a calcium-magnesium-bicarbonate type (Knapton, 1982).

Most surface water in the area is fit for irrigation during spring runoff and during the early irrigation season, but becomes deleterious to crops in late summer unless careful irrigation practices are maintained. All of the streams in the Bull Mountains are of sufficient quality to sustain wildlife and stock (Rioux and Dodge, 1980; U.S. Environmental Protection Agency, 1978).

Ground Water

Aquifer Description

Subsurface water in the Bull Mountains has been investigated by several individuals and agencies, primarily in relation to water supply and coal development. Ellis and Meinzer (1924) authored a paper on ground water in Musselshell and Golden Valley Counties. Hall and Howard (1929) produced a paper dealing with ground water in Yellowstone and Treasure Counties. Zimmerman (1956) reviewed the geology and ground water resources of parts of Musselshell and Golden Valley Counties. Rioux and Dodge (1980) tabulated hydrologic data for the Bull Mountain region. Knapton (1982) presented data regarding stream water quality in the area, and Thompson (1982) investigated ground water primarily in the southern portion of the Bull Mountains,

in relation to proposed coal mining activity.

Local residents rely heavily upon springs and shallow wells drilled into the coal-bearing Fort Union Formation to provide water supplies for both domestic use and livestock watering. Concern regarding ground water quality degradation as a result of past and proposed underground and surface coal mining has led to studies which have provided additional information relative to the area's hydrogeologic system.

Ground water is present in several stratigraphic units in the area, but only those above and including the Bearpaw Shale of Cretaceous age are discussed, owing to the scope of this report. In ascending order, the formations of concern are: the Bearpaw Shale, the Fox Hills Formation, the Hell Creek Formation, the Fort Union Formation, including in ascending order, the Tullock, Lebo, and Tongue River Members, and Recent unconsolidated alluvial deposits.

The Bearpaw Shale is a 600 to 700 feet thick series of gray to black shales which act hydrogeologically as a confining layer. The unit represents the practical base of the shallow aquifer system in the Bull Mountain region. The formation is relatively impermeable and does not contain an appreciable quantity of ground water.

The Fox Hills Formation conformably overlies the Bearpaw Shale and consists of approximately 400 feet of fine to medium-grained sandstone interbedded with varying thicknesses of gray shale and shaley siltstone. The Fox Hills Formation is a significant source of ground water east of the Bull Mountains (Thompson, 1982). Within the Bull Mountains area, however, the formation has very poor potential as an aquifer because it is fine-grained and clayey (Montana Bureau of Mines and Geology, unpublished data).

The Hell Creek Formation overlies the Fox Hills Formation and is divided into two hydrogeologic units. The lower Hell Creek beds, in the Bull Mountain area, are similar both lithologically and hydrologically to the previously described Fox Hills Formation. The upper part of the

formation consists of gray to yellowish-gray silty and clayey carbonaceous and bentonitic shale and siltstone with occasional partings of medium-grained silty sandstone. The upper part of the Hell Creek serves as a confining layer, and does not yield water to wells in the region (Thompson, 1982).

Overlying the Hell Creek Formation, in the Bull Mountain region is the Tertiary Fort Union Formation. The total thickness of the Fort Union in the Bull Mountain area is approximately 2,300 feet. The primary aquifers in the Fort Union include numerous coal seams, in addition to varying thicknesses of fine to medium-grained sandstone.

The lowest member of the Fort Union Formation, the Tullock, consists of approximately 350 feet of interbedded light to medium gray shale, light-gray fine-grained sandstone and siltstone, and thin but persistent coal beds. In some areas, the sandstone and coal beds provide water to wells; yields average about 15 gallons per minute (Stoner and Lewis, 1980). A few wells drilled into the Tullock at structurally favorable sites yield small artesian flows (Zimmerman, 1956).

The Lebo Shale represents the middle member of the Fort Union Formation. The lithology of the unit is dominated by a brown to black carbonaceous shale with occasional siltstone, sandstone, and thin coal partings. The unit is generally not considered an aquifer, although small sandstone pockets within the unit can yield adequate quantities of water for domestic use (Stoner and Lewis, 1980).

The uppermost member of the Fort Union formation is the Tongue River. The Tongue River Member represents the dominant rock unit exposed in the Bull Mountain region. The unit represents the most significant hydrogeologic unit in the Bull Mountains with respect to its prominence as a viable shallow aquifer. The Tongue River Member is about 1,900 feet thick in the Bull Mountains region and consists of interbedded sandstone, siltstone, and shale with numerous coal beds. The coal beds are the most laterally persistent aquifers in the area, while sandstone aquifers are of fluvial origin and tend to be lenticular

in shape and laterally discontinuous. Yields from wells completed in aquifers in the Tongue River Member are reported up to 30 gpm, but most are much less (Thompson, 1982).

Alluvial deposits of Quaternary age are found along all major streams in the Bull Mountains. The alluvium generally consists of a basal gravel layer overlain by fine-grained sand, silt, and clay. The gravel layer provides water to many wells in the area and is reported to yield water to the highest production wells in the Bull Mountains (Zimmerman, 1956).

Aquifer Characteristics

The coal aquifers in the Tongue River Member have been found to be strongly anisotropic; the directions of maximum and minimum hydraulic conductivity are apparently parallel to the coal's average face and butt cleat orientations, respectively (Stone and Snoeberger, 1977; Stoner, 1981). The maximum hydraulic conductivity is reported to be about three times the minimum in two coal aquifers tested by Stoner (1981). Hydraulic conductivity in the Mammoth coal seam has a lognormal mean of 0.1 feet/day, and sandstone aquifers, located both above and below the Mammoth, have a lognormal mean of 0.04 feet/day (Thompson, 1982). Storage coefficients in all aquifers tested indicate the presence of confined or semi-confined conditions.

The direction of ground water flow in the coal seams in the Bull Mountains is generally to the north and northwest (Thompson, 1982). It is generally thought that a primary component of ground water movement in the coal is downward. Numerous perched aquifers are present throughout the area due to lensy impermeable strata acting as aquicludes to downward movement of ground water (Stoner, 1981).

Groundwater Quality

The quality of ground water in the Bull Mountains region is diverse and depends on proximity to a recharge area and location in the

stratigraphic section. Thompson (1982) reports a range in specific conductance of 500 to 4,100 umhos/cm for samples collected from 40 wells and 13 springs in the Bull Mountains. Water near recharge areas is generally a calcium-magnesium-bicarbonate, low-dissolved-solids type. As the water moves through the system, its character changes to a sodium-sulfate-bicarbonate type (Thompson, 1982). Nearly all the ground water samples collected by Thompson exceeded U.S. Environmental Protection Agency (1975) secondary drinking water standards for dissolved solids and sulfate concentrations.

CLIMATE

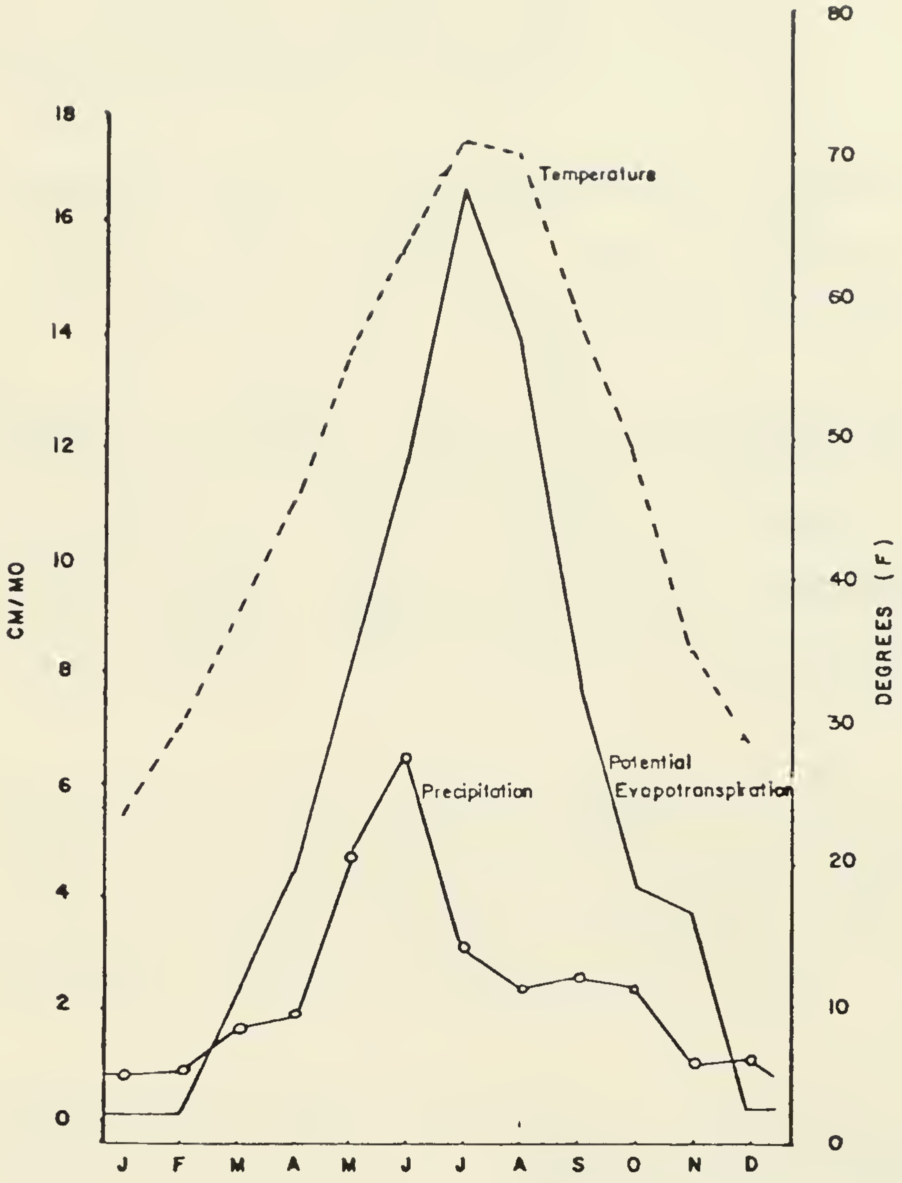
The climate of the area is continental and is characterized by relatively long winters and mild summers. Temperatures as high as 100°F and as low as -25°F occur regularly. Mean temperature for the area is 47.1°F.

The presence of the Bull Mountains results in slightly greater precipitation than the surrounding area. Average annual precipitation for Roundup is 11.64 inches. About 79 percent of the precipitation falls during the April-September growing season. The growing season averages between 115 and 120 days. However, water stress created by the 26.5 inches of potential evapotranspiration limits plant growth for most of the growing season unless stored water is available (Caprio, 1973). May and June are normally the wettest months. Figure 1 illustrates the yearly temperature and precipitation pattern for the study area.

VEGETATION/LAND USE

The vegetation is characteristic of both the plains and low elevation forestland. Roughly 50 percent of the study area is covered by a tree canopy consisting mainly of ponderosa pine (Pinus ponderosa) and Rocky Mountain juniper (Juniperus scopulorum) and 50 percent by Northern Great Plains range grasses (Ross and Hunter, 1976). Arno (1979) states that on south facing dry sites where present, the tree canopy is open with tree growth beteween 35 and 60 feet. While on

FIGURE 1.



northern aspects dense stands occur with the tree growth reaching between 70 and 95 feet tall. Ponderosa pine growing in the Bull Mountains is considered to be of the variety scopulorum with two fasicles per bundle rather than three as is commonly found further west. It is thought that this manifestation represents a distinct genetic difference between eastern and western trees.

The ponderosa pine forestland is generally found on sandy soils and is characterized by its own vegetation component. This forestland falls into the *Pinus ponderosa*/*Agropyron spicatum* (ponderosa pine/bluebunch wheatgrass) habitat type as defined by Pfister, et al (1977). On pristine sites such species as ponderosa pine, Rocky

Mountain juniper, bluebunch wheatgrass (*Agropyron spicatum*), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Boutloua curtipendula*), skunkbush sumac (*Rhus trilobata*), and western wheatgrass (*Agropyron smithii*) are found.

Sagebrush-grasslands within the study area are associated with siltier and more clay-like soil conditions. Such grasslands are found principally in the eastern foothills of the Bull Mountains and have been characterized by Jorgenson (1979) as the *Artemisia tridentata*/*Agropyron spicatum* habitat type *Agropyron smithii* phase (big sagebrush/bluebunch wheatgrass-western wheatgrass). On these areas, big sagebrush, little bluestem, western wheatgrass, needle-and-thread (*Stipa comata*), bluebunch wheatgrass, green needlegrass (*Stipa viridulis*), and blue grama (*Boutloua gracilis*) appear dominant.

Coulees throughout the study area encompass the other important habitat type within the Bull Mountains, the *Artemisia cana*/*Agropyron smithii* type (silver sagebrush/western wheatgrass). This vegetation community flourishes in areas of increased soil moisture.

Riparian forestland bordering the study area along the Musselshell River is composed principally of the *Populus deltoides*/*Symphoricarpos occidentalis* habitat type (plains cottonwood/western snowberry). *Salix* (willows) and mesic site shrubs are associated with this type.

The generalized range site for the study area is within the 12-14 inch precipiation zone on very shallow to deep loamy soils (Ross and Hunter, 1976).

Land use in the study area is principally for livestock grazing. Aprroximatley 70 percent is rangeland while much of the remainder is used for alfalfa hay production. Grazing in this region has been lighter than on most of the other areas of the state. Rugged topography and lack of stock watering facilities have allowed this area to remain relatively pristine. Estimated livestock carrying capacity for

the area is 3.5 acres per cow month with a potential of 3.0 acres per cow month (MAES, 1973).

Small acreages on benchland throughout the region has been cultivated for wheat production. Some timber harvesting occurs in the Bull Mountains but the site potential of these forestlands makes them better suited for livestock grazing.

SOILS

Existing soil maps are old and done at the very general mapping intensity of a reconnaissance soils survey (Gieseker, et al., 1953). An association of three major soil series is recognized for most of the Bull Mountains. The Bainville, Travessilla, and Flasher soil series are shallow (one-two feet thick) and often sandy. All are weakly developed as indicated by the youthful classification in the modern classification system. They are in the Entisol order because of a warm, dry climate (Torriorthents) or because of the dominance of sandy parent materials (Psamments) (Soil Survey Staff, 1981). The erosive conditions of the Bull Mountains that maintain such youthful soils will have a strong influence on the stability of reclamation efforts in newly exposed materials from coal mining (Packer, 1974).

Factors of Soil Genesis

Characteristics of the setting that affect soil development have been generally recognized in the previous descriptions of the study area in this report. More specific factors of soil formation will be discussed here. Weakly consolidated sandstones and siltstones which dominate the Fort Union Formation (Woolsey, et al., 1917) are easily detached when exposed to raindrop impacts or overland flow. Summer thundershowers can bring almost three inches of intense rain in a 24 hour period when average monthly precipitation is less than an inch (US Dept. of Commerce, 1971). The drying affects of an average potential evapotranspiration of five inches during July, August, and September makes lightning caused fire a normal part of the setting. Fire resistant

trees may protect rocky sideslopes from raindrop impact, but cannot stop the erosive forces of runoff during a heavy rain. The combination of erosive parent materials, found in relatively flat lying beds in a semiarid climate and associated sparse vegetation, has resulted in soils with peculiar topographic associations. Gentle slopes of the tabular divides and benches have had generally less severe erosion and, therefore, moderately deep soils. Soils become shallower on margins as slopes become steeper until the sideslopes of canyons have little soil and are dominated by rock outcrops. The toe slopes and small valley bottoms have deeper soils because of the depositional setting. If the valley becomes big enough for large volumes of runoff, erosion towards the lowering Musselshell River base level reduces the soil depth. Toe slopes may have deep alluvial deposits but only have shallow soil development because of the dry climate.

The factors of soil formation will affect reclamation treatments proposed as well as help in locating sources of borrow material.

The geochemistry of the Fort Union Formation in the Bull Mountains is expected to be similar to that of the Fort Union Formation in southeastern Montana. Overburden or spoil materials in the northern Powder River basin of southeastern Montana have significant levels of fluorine, mercury, lithium, thorium, and sodium compared to soils of that area (USDI Geological Survey, 1979). Other elements found in higher concentrations in shale than in either soil or sandstone are: boron, chromium, copper, fluorine, gallium, molybdenum, and nickel. Of those elements, sodium, boron, and molybdenum are considered important in routine assessment of overburden in determining reclamation potential of coal mines in Montana (DSL, 1983). Selenium is also considered a potential problem, particularly if vegetative indicators of selenium are present. High sulfur content of the coal in the Great Falls Coal Field is considered the cause of very acidic soils and waste pile materials (Noel, 1982). Sulfur levels in coal of the Bull Mountain area mines and Rosebud County mines of the Fort Union Formation are about 20 percent of the levels in the Great Falls Coal Field (Gilmour and Dahl, 1967). Bull Mountain waste piles are not expected to have

severe acidity problems like the Great Falls Coal Field. Characterization of problem areas is done with an awareness of the potential for toxic elements in this region and is an important factor of reclamation and fertility characteristics of the Fort Union Formation (Packer, 1974).

ENVIRONMENTAL IMPACTS

The Bull Mountain Coal Field in the area of Roundup, Montana, consists of thin, poor quality coal beds with a poorly indurated to massive sandstone. The sandstones are from the Tertiary Age Fort Union Formation and range from friable and thinly bedded to massive. Coal quality ranges from lignite to bituminous with high pyrite content. Both coal and sandstone are relatively flat bedded with dips of generally less than 14° from the horizontal.

Abandoned mine problems related to geotechnics are usually subsidence, instability of waste piles or hillside dumps, open portals, shafts, and loss of land. Subsidence is associated with flat bedded sedimentary rocks which are poorly consolidated or otherwise incompetent.

Gravitational, and possibly tectonic forces, act on rock containing underground openings in a manner tending to close the orifice. Part of the closure results from time independent or elastic deformations, part from the inelastic or time dependent deformations, and in almost all underground mines, a substantial amount of closure results from fracture of overlying rock. The net result is surface subsidence expressions.

Initial manifestations may be convergence of a succession of local failures (spalls) in the rock surrounding the opening, e.g., repeated falls from the roof. Surface subsidence may range from a barely discernable depression to deformation with the approximate volume of the original underground opening.

Surface subsidence is most often observed in relatively flat, thin-bedded deposits overlain by stratified sedimentary rocks which are poorly consolidated or otherwise incompetent. The Bull Mountain Coal Field provides excellent examples of this phenomena.

Generally, the first evidence of subsidence in a room-and-pillar or long wall coal mine is a downward flexing of the roof, possibly accompanied

by floor heave. As the areal extent of the mine increases, the roof sags until it touches the floor, or fractures and falls. For virtually all rock types, this phase is time-dependent and terminates with complete orifice closure. Surface subsidence, indicated by vertical and lateral surface displacement, occurs almost immediately subsequent to the first indication of subsurface movement. The displacements result in lateral surface strains that can increase with the increase in the dimensions of the mine and with time until cracks are produced.

Geotechnics have no wide environmental impacts unless one chooses to view the study area as a region. In this case, subsidence and mine openings are a definite impact, especially from a land loss standpoint. The two largest impacted areas are the Republic No. 3 Mine and the Roundup Mine. Coal slack and past combustion problems at the Republic site have ramifications for the community if left uncorrected. Subsidence at the Roundup Mine has and will continue to reduce the area available for agricultural use.

HYDROLOGY

Surface Water

Maintaining the quality of surface water is of prime importance to residents inhabiting the Musselshell River Valley and areas along major tributaries to the river. Abandoned coal mines in the Bull Mountain region represent one possible source of contamination to the area's surface water regime. Discharging mine adits have been shown to be detrimental to surface water quality at several locales elsewhere in Montana.

Most abandoned coal mines in the study area are located in small drainages tributary to the Musselshell River. The abandoned mines would thus have the greatest impact on drainages proximal to the sites. The detrimental effects on surface water quality will decrease with distance from the source due to dilution by tributary water to the affected trunk drainage.

The eventual recipient of surface water in the Bull Mountain area is the Musselshell River. The Musselshell is the economic lifeblood of the area providing water for both domestic and agricultural needs. Deterioration of the quality of water in the river would result in significant hardships to the local residents.

After a review of appropriate surface water quality data and field visits to designated mine sites, it is obvious that surface water degradation will not occur on a regional scale as a result of contamination by abandoned mines. Localized contamination is evident, although most mine sites are located adjacent to ephemeral drainages which diminishes their contamination potential. Only one perennial stream is affected by discharge effluent from a mine site. This mine, the Keene 26, is discussed later in this text. Other local impacts are present typically in the form of increased sedimentation rates due to coal slack and waste dumps adjacent to the streams.

In summary, based on available data and field observations, it is unlikely that the regional surface water regime in the Bull Mountain area is affected by abandoned coal mines. Localized contamination is evident at individual sites but the severity of the disturbance to local surface water is minimal or insignificant owing to the ephemeral nature of the mine sites' hydrology.

Ground Water

The effect of abandoned coal mines on the quality of water in subsurface strata in the Bull Mountains region represents a significant concern to local residents who use this water source for both domestic and agricultural needs. The MBMG conducted a well and spring inventory in the Bull Mountains and located 130 wells and 112 springs in an area approximating this report's study area. All but 16 wells and 5 springs obtain ground water from coal and sandstone aquifers in the Tongue River Member of the Fort Union Formation (Thompson, 1982). Approximately 60 percent of the wells inventoried are stock wells, 20 percent are domestic wells, and the remainder are unused. The

majority of springs recorded are developed for stock useage. It is evident that ground water in the Tongue River Member represents the most significant source that may be impacted by past coal mining activities both because of its proximity to the surface and its development as a water supply.

Regional Impacts to the Ground Water Regime by Abandoned Mines

Following an inventory of abandoned mines outlined in this study, it is evident that these sites have an insignificant impact on the regional ground water regime in the Bull Mountains area. Of the mine sites inventoried, only one, the Keene 26, was observed to discharge ground water. A discussion of the impacts of Keene 26 discharge is included later in this text. The remainder of the sites give no indication of ground water impacts to the regional system, as most mine workings followed relatively thin coal seams which are commonly dry.

Existing stock and domestic wells are unaffected by the abandoned mine sites inventoried. This is because none of the wells identified are located in the immediate vicinity of any of the mine sites and because the aquifers in which most of the wells are completed were not affected by mining activity. Any degradation to the quality or quantity of the water in these wells is, therefore, unlikely in the future.

Evidence of subsidence-related impacts to the regional ground water system was not observed at any of the inventoried mine sites. If subsidence occurs at these sites, the effect would likely be localized and the regional ground water regime would remain unaltered. There is no evidence to suggest any impacts to the utility of the regional ground water system in the Tongue River Member as a shallow ground water source for domestic and agricultural needs.

Land Use/Vegetation

Impacts to adjacent land uses were observed at all study sites. The quantity of waste material and amount of mining-related disturbances

determined the extent of impacts.

At most sites, disturbance areas showed good reinvasion and stabilization by native and aggressive weedy species (TABLE B). The prinicipal plant species found invading disturbance sites were generally consistent between sites but did vary on occasion in response to the available moisture.

Deeply held water and only slight toxicity of coal waste and overburden material were the main factors responsible for the invasion of some deep-rooted vegetation on some sites. On sites without vegetative cover, acidic conditions, the lack of available plant nutrients, droughty soils textures, and elevated soil and surface air temperatures were the principal limiting factors.

The quantity of weedy species at abandoned mine sites within the study area reduced the land use potential of the site. In general, weedy species are without economic value to the landowner, although certain plants may have some utility to wildlife in the form of food and cover.

SITE SPECIFIC IMPACTS

Nelson Mine

The Nelson Mine is located about 1.5 miles southwest of Queens Point in Section 18, T9N, R30E (Map 1). The impacted area contains less than five acres. The site is in an uninhabited area, although it is adjacent to a county road.

The workings consist of an open adit on the south side of the road approach, three subsidence holes on the north side of the road and several large slack piles further to the west. No mine plans or maps are available for this mine.

The adit is located within a pasture and is accessed by a trench which is 28 feet long, 15 feet wide, and eight feet deep. The portal is

TABLE B. Plant species colonizing abandoned mine sites in the Bull Mountain Coal Field.

DRY SITE SPECIES

Scientific Name	Common Name
TREES:	
Pinus ponderosa	ponderosa pine
SHRUB/SUBSHRUBS:	
Artemisia frigida	fringed sagewort
Artemisia tridentata	big sagebrush
Ceratoides lanata	winterfat
Rhus trilobata	skunkbush sumac
Xanthocephalum sarothrae	broom snakeweed
GRAMINOIDS:	
Agropyron cristatum	crested wheatgrass
Agropyron smithii	western wheatgrass
Aristida longiseta	red threeawn
Bromus japonicus	Japanese brome
Bromus tectorum	cheatgrass brome
Oryzopsis hymenoides	Indian ricegrass
Stipa comata	needle-and-thread
FORBS:	
Achillea millefolium	yarrow
Asclepias syriaca	common milkweed
Astragalus purshii	pursh locoweed
Centaurea maculosa	spotted knapweed
Chenopodium album	lambsquarters
Cirsium arvense	Canada thistle
Convolvulus arvensis	field bindweed
Cynoglossum officinale	houndstongue
Descurainia pinnata	pinnate tansymustard

TABLE B. continued

DRY SPECIES

Scientific Name	Common Name
Grindelia squarrosa	curlycup gumweed
Kochia scoparia	summer cypress
Melilotus officinale	yellow sweetclover
Tragopogon dubius	salsify

WET SITE SPECIES (will include above)

Scientific Name	Common Name
SHRUBS/SUBSHRUBS:	
Prunus virginiana	chokecherry
Ribes setosum	squawbush sumac
Rosa sp.	rosa
Symphoricarpos sp.	snowberry
GRAMINOIDS:	
Bromus inermis	smooth brome
Calamagrostis canadensis	bluejoint reedgrass
Carex sp.	sedge
Distichilis stricta	inland saltgrass
Poa pratensis	Kentucky bluegrass
Stipa viridula	green needlegrass

partially collapsed and the trench has been filled with garbage. A competent, massive sandstone surrounds the portal with no observable signs of weakness or creep. No subsidence features were observed along the alignment of the adit or in its vicinity. A partially open incline is located near the north edge of the road and extending a portion of the way under the road. This incline is only open for about 15 to 20 feet and is filled with rock preventing any further access.

Three surface depressions are located approximately 500 feet northwest of the adit just described. The largest is 21 feet in diameter and 8 feet deep. It has been filled with timber and debris. The edges are well-vegetated and the sharpness of recent ground break is missing. The second subsidence feature is located 75 feet northwest of the first depression. It is 4 feet in diameter and 2.5 feet deep. Vegetation appears to be well-established. The slopes appear to be stable as well. The third depression has been backfilled recently and may be the entrance associated with the other subsidence features. A search of the area did not locate another adit or portal.

The depressions and the access trench have internal drainage and could lead to the development of acid waters. Subsidence is minimal and confined to a relatively small area.

Unvegetated coal piles and a partially vegetated shale pile are spread across the area. The gray colored shale material associated with coal waste at this site was sampled for analysis (Sample #1, Table 3, Appendix A). The sample had a high silt content, near neutral soil reaction, and low electrical conductivity. Nutrient levels are higher than most bedrock materials. Only phosphorus is very low.

Rangeland is the land use for the surrounding area. Sagebrush-grassland is found along the drainage and ponderosa pine-grassland on adjacent sandstone ridgetops. Range condition was considered to be fair.

Existing hazards consist of the partially collapsed adit and partially open incline. Hazards are considered moderate to severe.

Keene 26 Mine

The Keene No. 26 mine site is located in Section 26, T9N, R30E, about 30 miles east of Roundup and 11 miles southwest of Melstone, Montana (Map 1). The area is largely uninhabited. Workings are composed of several abandoned buildings and coal facilities, and a concrete-lined portal. There are several subsidence features including the collapsed adit and two smaller depressions. Water is collecting near the portal and discharges from the mine itself. The portal and adit are concrete lined for about 50 feet. The adit strikes south 65° east and has no apparent dip.

Overburden is a mixture of clay, sand, and silt underlain by poorly cemented, highly friable sandstone. Overburden thickness is 5 to 10 feet where observable. The rock is thinly-bedded and appears to exfoliate as it creeps around the adit orifice. Thickness over the coal bed probably increases with land surface rise to the south and southeast. Complete subsidence has occurred in the adit for the first 65 to 70 feet beyond the concrete liner. Examination of the head scarp indicates that subsidence will continue as evidenced by rock exfoliation. Two smaller subsidence features were observed about 500 feet southeast of the portal. The depressions are on the same alignment as the adit and appear to be very recent. Both are 10 to 12 feet in diameter and three feet deep. The depressions are in a drainage and probably act as infiltration galleries for the mine. Overall, subsidence is limited but potentially active.

The Keene No. 26 Mine represents the only discharging mine of those inventoried for this project. The discharging adit is adjacent to Carpenter Creek, a perennial tributary to the Musselshell River. The major hydrologic concern relative to the Keene 26 is the impact of the mine discharge on the quality of water in Carpenter Creek, in addition to associated impacts to the Musselshell River, the eventual recipient of the discharge.

To quantify the impact of the Keene 26 effluent on the adjacent stream,

water quality samples were obtained on May 25, 1983 from Carpenter Creek upstream from the mine discharge and downstream, below all mining related disturbance. In addition, a sample was collected from the mine discharge. The analytical results of this sampling program are contained in Appendix B.

At the time of sampling, discharge of the Keene 26 mine was estimated at six gallons per minute (gpm). Examination of the water quality analysis indicates the water is a moderately saline, very hard, magnesium-sulfate type which exceeds secondary Federal drinking water standards for sulfate, magnesium, iron, and total dissolved solids (TDS).

Water quality analyses for Carpenter Creek indicate the water to be a slightly saline, very hard, magnesium-sulfate type which exceeds secondary Federal drinking water standards for sulfate and TDS. In addition, concentrations of manganese exceed secondary standards for the water sample obtained below the Keene 26 discharge. Flow in Carpenter Creek at the time of sampling was estimated at 50 to 60 gpm.

A comparison of Carpenter Creek water quality analyses from above and below mine discharge (Appendix B) indicates a noticeable increase in concentration of several parameters. The increase is insignificant, however, relative to the general character or useability of the water. Although not fit for domestic use, Carpenter Creek remains of sufficient quality to support wildlife and livestock both above and below the Keene 26 discharge site.

The effluent from the mine contains elevated concentrations of sulfate (2370 mg/l) and TDS (2460 mg/l) and as a result is not recommended for either stock or wildlife. The level of concentrations are not toxic but are considered to be deleterious to animal growth.

The major waste material of this mine is piled along the stream channel north of the tipple. The shale-rich material has coal mixed with it but not in burnable quantities. Physical and chemical properties of the

material are some of the poorest encountered in the Bull Mountain Coal Field. The slope of the gob pile breaks sharply at the drainage edge with gradients of up to 70 percent. Most of the top of the gob pile is unvegetated gray compact shale-rich wastes. Small piles of coal have been concentrated in some areas on the north end which have some vegetation being re-established. Shrubs and a few grasses are present. Some gray areas have inland saltgrass (Distichlis stricta) and other salt tolerant invaders. Sheet erosion occurs on the surface and gully erosion is occurring on the steep bare sideslopes. A white salt crust lines the toe slopes where sediment is being deposited.

Samples from the unvegetated eroding south end were taken to about two feet for lab analysis. A sample of the partially vegetated coal was also sampled. Clay content is the highest of any material sampled and is the major factor in the hard surface crust. Sodium adsorption ratios are low and not a problem. Electrical conductivity (EC) is also higher than other areas and high enough to inhibit plant growth. Capillary movement to the evaporating surface has given the top few inches the highest EC. Erosion of this highly salty material probably accounts for the white crust near the stream. The most acidic material is also found at this site with a pH of 2.9. Acid-base analysis shows the largest negative acid-base potential of the three areas tested (Appendix A). Organic and sulfate-sulfurs are the primary cause of acidity. Boron levels are also the highest of any material tested. They are not high enough, however, to prevent plant growth. Fertility is low as in most other waste materials. Organic matter is high due to the relatively inert coal which does not add to nutrient holding capacity or nutrient levels in the shales. Compaction of the surface encourages runoff so little leaching takes place and salts stay in the material.

The small piles of apparently windblown coal are very permeable and have had salts leached out. Electrical conductivity is only 33.0. Reaction is still acidic (pH 3.6) but not low enough to inhibit plant growth. Nutrients are more abundant in the coal than other wastes with more than adequate levels of nitrate-nitrogen and potassium. Phosphorus is still deficient and will remain so until pH is raised. The

coal piles represent a minor part of the area and were tested only to indicate what permeability might do to reduce salinity.

The adjacent land use is for cattle grazing. Reasonably productive range grasses and adequate water make this a suitable location for such an enterprise.

The main hazards associated with this site include the open portal, a small subsidence area, and a collapsed roof over the main adit beyond the portal. A collapsed tipple and loadout facility, several old structures, and building foundations are present and pose potential hazards. Extensive debris and other mine related materials are scattered throughout the area. The inventory conducted by DSL indicates an open shaft 12 feet by 12 feet by 40 feet is located on the site. An extensive search was made during the two site visits for this shaft, but no evidence of an open shaft was found.

Carpenter Creek Mine

The site is located in the Queens Point Quadrangle approximately six miles southwest of Melstone on the Carpenter Creek Road. It lies in Section 20, T9N, R30E (Map 1). The site is uninhabited but is close to a county road. The impacted area is estimated to be less than ten acres.

The primary impacts are several old concrete foundations, building remnants, and footings which are located throughout much of the area. Mining debris is strewn about and several low profile mine waste dumps are present. There are no serious safety hazards at the Carpenter mine; however, the abandoned mine wastes, debris, and structures have caused significant environmental degradation and are impending health hazards to persons or livestock.

A small pile of slack coal at the site has a low potential for spontaneous combustion since it is more than six inches in most areas and is nearly pure loose sandy to gravelly coal. It is considered to have properties

like other coal piles making it unsuitable for seedling establishment. Adjacent to the coal are soils developed in alluvium and colluvium derived from shales and some sandstone which have fine loamy textures and signs of recently added salts.

Surrounding land use is for livestock grazing and is similar to other mines in the eastern part of the Bull Mountain Coal Field. Basic vegetation consists of both sagebrush and range grasses. The increased presence of western wheatgrass (Agropyron smithii) indicates siltier textures are present.

Nies Mine

The Nies Mine is located in Section 17, T8N, R25E (Map 1). Although only one mine is listed by DSL, another working mine was discovered approximately ¼ mile southwest of the study site. For discussion purposes, the original site is labeled No. 1 and the discovered mine as No. 2. One residence is adjacent to the No. 1 site which is also near a main county road. Approximately five acres is disturbed at the No. 1 site and another two acres at the No. 2.

Mine No. 1 consists of an adit which is partially caved and striking south 60° east. The portal is 10 feet by 5 feet and has a horizontal floor. The coal seam is 18 inches thick and overlain by thinly bedded, poorly indurated, and somewhat silty sandstone. A hole 15 feet in diameter is located behind the portal. Both features are located in an access trench. No signs of subsidence were noted.

Mine No. 2 is located about 1,200 feet southwest of the original site. It consists of two adits, several subsidence features, and several dumps. One adit strikes south 10° west, with a horizontal floor, while the other strikes north 75° east, and also has a horizontal floor. Rock is a buff-colored sandstone ranging from thinly laminated to about four inches in bed thickness at the first adit. Massive sandstone about 3 feet thick and overlain by highly fissile sandstone comprises the second adit. Portal sizes are 6 feet by 4 feet at the first and 12 feet by 4

feet at the second.

Subsidence features are associated with both adits. A circular feature 10 feet in diameter and 7 feet deep is located 35 feet southwest (upslope) from the first adit. Land surface rises to a small bench where there is a large hole about 16 feet deep. It appears to have been ramped for excavation in the past, but could also be a subsidence feature. Topography rises again from the bench to the final crest. On strike with the adit is a kidney-shaped subsidence about 45 feet long, 20 feet wide, and 1.5 to 2.5 feet deep.

A small circular depression is located about 190 feet north 65° east, of the second adit and 240 feet south 65° west, of the kidney-shaped subsidence feature. The depression may be an air or hoisting shaft because of excavated earth around the perimeter.

Subsidence appears to be relatively young and rock type would be conducive to continued movement.

A large pile of slack coal at Mine No. 1 has a moderate potential for spontaneous combustion and has characteristic properties making it a poor plant growth medium. Trees and shrubs are invading the margins but little or nothing is growing on the thick coal except where shaded by the adjacent forest.

Land use on benchland above the Nies Mine site is used for cattle grazing but the shallow coulee in which the mine sits and the adjacent tree covered sideslopes have little utility. A small house next to the site is currently occupied. Dense vegetative cover in the coulee is provided by the silver sagebrush and ponderosa pine on the hillsides. The area possesses good wildlife habitat.

Significant safety hazards exist at the No. 1 site. These include an open shaft partially covered with deteriorated timbers, and a partially open haulageway. An old explosive bunker with a rock-wood structure around the entrance is located on the hillside. An extensive tipple,

wooden trestle, and load-out structure are still erect. The tipple and load-out facility is badly deteriorated and is extremely hazardous. Several old structures in varying states of disrepair, several mine waste dumps, and a high earth/waste ramp, which is part of the load-out structure are also located on the site. The area is an unattractive nuisance, is highly unsafe, and is an impending danger to anyone walking within the boundaries of the mine. Hazards at the No. 2 site are restricted to the open adit.

Square Deal Mine

This mine is about three miles west of Roundup in Section 17, T8N, R25E (Map 1). The workings consist of a largely reclaimed area of mining on a low bench, a quarter-mile long haul road, several dilapidated structures, and slack piles near the county road. The adit has been covered following the cessation of mining in the early 1970's.

Coal piles are relatively pure and lack a good plant cover. They are small in size and have a near neutral pH. The piles of sandy coal-free waste have a good vegetative cover on the north aspect suggesting water availability as the main reason for lack of vegetation on south aspects.

A related disturbance area is located at the end of the haul road. It consists of a shallow depressed area approximately 40 to 60 acres in size and appears to be a coal storage area. Several small coal piles and coal slack are present in addition to minor debris. The area is almost completely revegetated.

Surrounding land use and vegetation at this mine is similar to that found at the Nies Mine. The direct mine-related disturbance area represents from five to ten acres.

Physical hazards are limited to old buildings, loading structure, scattered debris, and mine waste piles. Hazards are low to moderate in severity and there are no serious threats to life or safety.

Johnson Mine

The Johnson Mine is located in Section 9, T8N, R25E (Map 1). Workings consist of a large portal about 12 feet by 8 feet, a gob pile, and a significant subsidence feature. Approximately five acres have been disturbed by this mine.

The main adit strikes south 70° west, with a downward dip of about 10°. This adit is about 480 feet long. It is shored with timber cribbing for the first 50 feet as it passes under the county road. A lateral extends off the main adit about 190 feet from the portal, striking about North 65° West. This lateral is about 1400 feet long. Overburden thickness is on the order of 1 to 2 feet and roof thickness on the order of 8 feet. Examination of bedrock shows a slightly cross-bedded friable sandstone, which has undergone significant stress relief. No evidence of distress was observed in an adjacent building.

A significant subsidence feature is clearly visible beyond the building and on the strike of the lateral. It is important to note that the building sits on a slight knoll where bedrock outcrops. The surface slopes downward beyond the building at about 10°. The subsidence occurs as a depressed area about 500 feet beyond the building. Width ranges from 30 to 45 feet. Several small circular depressions are located within and beside the larger depression.

Little or no wastes are at the mine shaft near the edge of the road. Most are associated with another adit to the northwest. Materials there are mainly sandstone overburden. No significant hazards from toxic elements are indicated. Low water holding capacity of sandy materials is the most significant problem for reclamation of this area.

The immediate area is residential/commerical with a residence and shop. The open portal at the Johnson site is very hazardous and poses a real danger to all vehicles driving the county road atop this adit. The existing buildings and trailer house located above the old Johnson Mine

workings may also be in danger due to instability of the roof over the tunnels.

State Section 16 Mines

The State Section 16 Mines are located approximately four miles east of Roundup on a major county road, and in the vicinity of the Johnson, Square Deal, and Nies Mines (Map 1). Section 16 Mines consist of three workings, none of which have open adits and are only evidenced by tipple ramps and other features. The mines are probably a portion of one or all of the above-mentioned mines.

The first mine site is located at the northeastern edge of Section 16. The workings include a large pile of mine spoils forming a ramp striking south 45° east. A large hole is located approximately 45 feet southeast of the toe of the ramp. This hole is 18 feet in diameter and full of debris a minimum of 10 feet deep. This feature may be a shaft or a subsidence pipe just behind the portal of a caved adit. The sides of the depression are nearly vertical and show no bedrock. This area appears old and stable.

A second ramp is located about 1,000 feet west of the first site. This ramp is located in the bottom of a large draw, striking south 57° west. An adit may be located at the toe of the ramp.

A third trench and caved adit are located approximately 250 feet northwest of the second working. This site appears to have been a small adit striking south 62° west. The trench is 40 feet long, 5 feet deep, and heavily vegetated.

Piles of slack coal are widely dispersed through the pine trees and in small openings. The coal is nearly pure and often one half to one foot thick. It is thin enough in many areas to allow establishment of pines. Other waste piles were not observed.

The subsidence hole or caved adit is located less than one-quarter mile

away from a residence. For this reason it should be considered a potentially serious hazard.

Keene 28 Mine

The Keene 28 Mine is located just northwest of Highway 12 (Map 1), four miles southwest of Roundup, in Section 28, T8N, R25E. The site is located adjacent to a farm containing a residence, several buildings, and corrals.

The main workings consist of a backfilled shaft, several footings, and a small coal slack pile. Secondary workings are located next to the farm buildings and include a small open portal, a large excavation, and several waste dumps. A small subsidence area above the portal has been used as a trash dump. A large open shaft 14 feet in diameter and 20 feet deep is located above the portal. Residents are currently using it for trash disposal.

Both coal and overburden piles were sampled at Keene 28. The coal (Sample #30) is two-four feet thick, coarse textured and loose. A very fine grained and thin layer of coal (Sample #31) is almost completely revegetated with grasses. Sandstones dominate the other waste piles which have a moderate cover of invading grasses, forbs, and shrubs. The presence of shales keeps the texture loamy and a near neutral pH reduces fertility problems.

Significant hazards to residents of the farm are present at the Keene 28 Mine site. The existing shaft and open portal pose obvious safety hazards to these people.

Jeffries 4 Mine

The Jeffries 4 Mine is located on isolated ranch land in the Gage Quadrangle about ten miles south of Roundup (Map 1). The workings consist of four adits (three caved and one open) and several small slack piles.

The open adit is located to the east of the access road. This adit is readily accessible and strikes south 80° east, while inclined at 11° downward. It is overlain by a moderately friable, 1 to 3 inch bedded, easily weathered sandstone. The sandstone is sagging above the adit and includes very competent, massive sandstone outcrops. No subsidence was located in the immediate area of this opening. Two smaller adits are located adjacent to this one, both with collapsed openings. A fourth adit is located across the drainage to the west of the others. This adit is caved and the trench below is filled with debris. The geology is identical to the other three adits. No subsidence is evident in the area.

Coal piles are found scattered downstream from the mine along the drainage channel and on the bench above it. These are from one to four feet thick, nearly pure piles of loose gravel and sand size coal. Like others in the area, they have shrubby vegetation establishment along the margins but with little or no grasses or forbs on the pile. Chemical properties are expected to be like coal piles sampled at the Western Mine.

The safety hazards are serious and pose a significant threat to persons who may enter the adits; however, the area is remote and is not easily accessible because of two locked gates which prevent road travel into the site.

Cooper Mine

The Cooper Mine is located in the Signal Mountain Quadrangle along a small draw just west of Highway 87, and approximately eight miles southwest of Roundup (Map 1). Workings consist of one open adit (4 feet high and 18 feet wide) located near several residences. Several small slack piles dot the area. No mine structures remain nearby.

The adit is located in a massive, structurally competent sandstone which overlies a horizontal, 3 feet thick coal seam. No surface subsidence is associated with the adit and the back shows no signs of failure. The

open adit presents a hazard, due to its proximity to the highway and nearby residences.

Residential housing nearby appears to be the only land use for the area.

The open portal and adit constitute an extreme hazard to curiosity seekers and/or children of area residents.

Western Mine

The Western Mine, which is still actively used but not mined, is located in Section 4, T7N, R26E (Map 1). Workings consist of two adits, a tipple, and several support buildings. The disturbance area represents over ten acres.

The first adit is still in use and leads to an underground mushroom plantation. It forks just beyond the portal with one fork striking south 70° east, and the other south 40° east. The adit is driven through interbedded laminar and thick (one-three feet) sandstone beds; orientation is approximately horizontal. Timber cribbing extends about 100 feet into either fork of the adit, but some roof sag was observed.

The second adit is on the order of 400 feet west of the first adit. It is partially caved, strikes due south, and is driven in a fissile laminated sandstone overlain by a thickly bedded sandstone.

Subsidence was not observed in either location, although there could be roof problems at both locations. From discussions with the owner it was learned that he plans to retain its present land use and continue to operate the mine as a plantation in the foreseeable future. He also wants to maintain access to the main underground workings through the second adit.

The drainage bottoms and margins for about 200 yards downstream from the mine have scattered piles of slack coal of varying thickness.

Properties of the coal are represented by Sample 2 (Appendix A). The black color, coarse texture, and moderately acid pH are the main problems for seedling establishment. Deep-rooted trees and shrubs are growing vigorously on many areas. Another coal pile is found on the ridge immediately south of the mine. The southerly aspect and steep slopes in combination with poor physical character make this more of a problem for revegetation than most coal piles. Other wastes without coal are not extensive and have few problems with revegetation.

The large wooden tipple structure is still erect although it is gradually deteriorating and relatively unsafe. The several old structures are in varying stages of disrepair. The site is believed hazardous due to the existing tipple and the open portal and shaft. The main haulageway and tunnel structure do not present any major hazards; however, the entryway should probably be enclosed to prevent unauthorized access.

Roundup Coal Mine (Williams Mine and Davis Mine)

The Roundup Coal Mine is located on the south side of Roundup in Section 23, T8N, R25E (Map 1). The Musselshell River forms the north boundary of this study site. Workings consist of two adits, numerous subsidence features, and a large inclined portal which reportedly belongs to the Republic No. 3 Mine.

The first adit is located on the river bank about 30 feet above water level and is six by five feet; the floor appears to be horizontal. The adit is driven in a thinly bedded sandstone with ¼ to ½ inch beds and poor strengths. It is overlain by eight feet of more sandstone followed by ten feet of interbedded silty sands and gravels. The adit strikes south 65° west.

Subsidence in the area is significant, but apparently confined to the 30 acre bench which is used for agriculture. Reportedly, the major subsidence began in 1963 with the use of irrigation for crops. Features range in age from active to those which have stabilized and revegetated. Subsidence takes the form of circular surface orifices

indicating collapse of a room by formation of a "funnel", and long trench-like depressions indicating haulage or travel ways. Subsidence is so active that features mapped in June, 1983, did not appear on February, 1983, aerial photographs.

Size of circular features range from 10 to 25 feet with depths of 5 to 18 feet. The linear features are generally 10 feet wide (approximately), and 1 to 2 feet deep. Subsidence features also indicate room-and-pillar mining with occasional haulageways. The alternating pattern of subsided and undisturbed zones lead us to believe that pillars were not robbed on retreat.

The large inclined portal is located at the western end of the study area. It reportedly developed after another open adit or entry was filled. The open area is 21 feet deep and still subsiding. Reportedly, it is connected to Republic No. 3 Mine, which is 340 feet below grade.

Mine waste piles are a minor consideration compared to the subsidence. There are a few piles of coal-free wastes near the Musselshell River which have become revegetated. Water holding capacity of the top 4 feet of silty rich alluvial deposits is low to moderate (Appendix A). Below 4 feet, sand and gravel content becomes high enough to have a very low water holding capacity. The site sampled probably represents the lower half of the main subsidence area. Depth to gravels appears to decrease towards the south and west and increase to the north and east. Near the incline on the west end of the meadow, gravelly alluvium is found within 3 feet of the surface. Samples from that area (Samples 15 and 16, Appendix A) have lower general water availability than the materials in the central portion of the subsidence area (samples 18-21, Appendix A). Nutrients are also low in the main subsidence area. Phosphorus in the 2 to 4 feet sample (sample 20) is adequate and potassium in the top foot is high. Near the adit there is adequate phosphorus in both depths sampled but low potassium and high nitrate- nitrogen at depth.

The subsidence "pot holes" evident above abandoned workings present

localized hyrologic impacts. These sinks act as local recharge areas to the terrace alluvium from sheetwash runoff, direct precipitation, and sprinkler irrigation. These subsidence features provide avenues for artificial recharge of the unconsolidated terrace material and underlying, structurally weak, elastic bedrock. Artificially recharging the unconsolidated material via these subsidence features tends to increase the saturated thickness of the strata. With an increase in saturated thickness, the susceptibilty of additional unconsolidated material to shift increases, rendering the hydrologic impact of the "pot holes" significant. Increase of subsidence surface area will likely compound the problem as more artificial avenues of recharge to the terrace gravels are exposed.

An ephemeral drainage located east of the subsidence features has been impacted by discharge from a former dewatering well for Republic #3 mine workings. The discharge point was located approximately one-half mile south of the Roundup Mine adit and is adjacent to the affected ephemeral drainage. It is reported that large volumes of water were periodically discharged from this site resulting in artifical erosional cuts into the drainage. Presently, the channel is incised 10 to 15 feet below its former base level. The current landowner has reported loss of cattle as a result of their falling over these escarpments.

Fields surrounding the study site have been developed as irrigated alfalfa hayland. Until irrigation caused subsidence features to develop, the affected area was hayland as well. Winter feeding of cattle also takes place on adjacent hayland as does calving. The property owner reported several instances of cows and calves dying after falling into subsidence features on his property.

Subsidence has limited the usefulness of the land and presents a danger to cattle and anyone working in the fields. The entire mining site is extremely hazardous and is a significant threat to persons, livestock, and farming activities. Because of the significant safety threat to all activities and persons in the area of the mine and its close proximity to Roundup and to farming, this site ranks as extremely significant.

Republic No. 3 Mine

The study area is located in Section 14, T8N, R25E, about one mile west of Roundup on Highway 12 (Map 1). The impacted area is large, between 10 and 15 acres, and is close to both residential and commercial areas. There are no visible entries for access into the underground workings, which according to archive maps, are very extensive.

The waste piles in SE¼ Section 15 contain two major types of material. Coal rich wastes make up most of the northwest end while the east end is dominated by shale rich wastes with little or no coal. Samples were collected from two areas in the northwest representing strong (samples 3-6, Appendix A) and moderately strong (samples 7-10) coal influence and one in the southeast (samples 11-14) representing shale dominated waste. Samples were taken from ten inch depth increments to indicate effects of leaching on chemical status.

Coal in the west end is not pure and has moderate amounts of silt and clay that relate to the grayish color of the wastes. The light gray shale rich wastes (samples 11-14) of the east end are loams with almost twice the silt content of the nearly black coal (samples 3-6). Silt content in the shale has nearly doubled the water holding capacity of the coal rich wastes. Shale rich wastes have less impact than those with coal because of better nutrient conditions associated with the neutral pH. Shales are compactable due to high clay and sodium content (SAR is 4.2-9.7). Vegetation has a hard time becoming established naturally, though proper treatment makes reclamation feasible.

The potential for spontaneous combustion of the coal-rich materials of the west end is high making them a poor medium for plant growth. The location of coal rich wastes in relation to structure is also a significant impact due to fire hazard.

Coal slack piles are of primary interest at this site and include coal slack in the Gebhardt Post Yard and a large 10 acre dump to the

northwest of the post yard.

The post yard has had at least two burns (and possibly three) within the slack. The first was extinguished using a Bureau of Mines design which consisted of compacted fill over the burn area. A second burn occurred under a slab pile and apparently burned itself out, although the yard operator was reported to have applied water to the area. A third occurrence involved the creosote pot, but further information is lacking.

Borings drilled near the slab pile, sawdust pile, and saw mill indicate a thin layer of slack underlain by sandstone derivatives and sandstone (Appendix C). Temperatures of the slack were close to ambient air temperatures at the time of drilling. This places them slightly above what would be considered normal.

The dump is located northwest of the yard and contains extensive slack deposits. Borings show slack thickness ranges from 4 to 25 feet and is underlain by sandstone and sandstone derivatives. Internal temperatures are slightly elevated.

The area of greatest hydrologic impact is the portion of the mine site northwest of the former shaft entrance. The major shaft entrance and associated coal slack piles and waste dumps are located in this vicinity. The slack piles and waste dumps possess an irregular topography and are largely unvegetated. The piles are in an excellent position to contribute sediment to a small drainage present within the area. This is because the slack and waste dump are adjacent to the channel and in specific areas, they have enveloped the drainage.

Although the drainage is ephemeral, runoff from the drainage area above the channel is retarded by the slack piles. Because of this, the potential for saturation of the slack piles is significant. Saturation of the slack piles could constitute a hazard concerning their susceptibilty to combustion.

Both areas present hazardous conditions with respect to spontaneous combustion of the slack. The hazards in the post yard are exacerbated because the slab and sawdust generate heat as well. Additional hazards include a basement wall, floor slab, and headframe foundation. These are considered moderate.

Berten Mine

The Berten Mine, last worked in the 1930's, is located in Section 2, T5N, R25E. The impacted area is less than 5 acres. Two adits are present, one of which is accessible and the other partially blocked off. An old tipple structure which is nearly collapsed and a loading ramp are located in a coulee in front of the main portals. The hillside upslope and above the main portal is subsided and has been used as a garbage refuse area. The coulee below the mine working area also contains an old building and scale shack.

Adit number 1 is 8 by 6 feet and strikes north 25° east. The floor appears to be horizontal. The portal and adit are driven in a blocky, fractured, and jointed sandstone. Strength appears poor because the back of the portal has sagged badly.

Three subsidence features are associated with this adit. The first is located on a bench above the adit and 40 feet downstrike. It is 16 feet in diameter, 3 feet deep, and partially filled with trash. Sides are at the angle of repose, indicating no recent movement. The second feature is located 35 feet upstrike from the first. It is 3 feet in diameter, 2.5 feet deep, and daylights into the mine under the north lip. Movement is probably continuing. The third feature is approximately 100 feet downstrike from the adit. Average length, width, and depth are 50 feet, 20 feet, and 3 feet, respectively. Several sections of scarp appear fresh, especially near the north end.

The second adit is 200 feet south of the first. It strikes north 40° west, and has a 7.5 by 4 feet high portal. The coal seam is 18 inches thick and is overlain by massive sandstone. No evidence of subsidence

was observed near this adit.

Coal rich wastes near the bottom of the draw run from the mine mouth downstream. Shrubby vegetation is becoming established in the acidic coal, which has a pH of 4.0 or less. The sandy texture and high porosity make it similar to most coal piles in the area as a poor medium for seedling establishment.

A long narrow pile of shale rich wastes runs east from the mine shaft creating a dam across the small drainage originating northeast of the site. Portions of the pile are dominated by sandstone fragments and have a moderately well established cover of grasses, forbs, and shrubs. The far east end and pockets in other areas which are rich in shale have little or no vegetation. Low pH and crusting of the shales form the major impediment to vegetation establishment.

The area has been developed for livestock grazing. A watering trough at the head of the drainage ensures cattle access to the area. Surrounding vegetation on the benches provides grazing. Cover and the presence of water provides quality wildlife habitat in this area.

The two open portals, subsided area, and old tipple structure are significant hazards to the safety of persons and livestock. As the mine is somewhat isolated, the potential for a catastrophic occurrence is limited.

Musselshell Mine

The Musselshell Mine is located three and a half miles southwest of Roundup in Section 23, T8N, R25E and was formerly part of the Republic No. 3 Mine (Map 1). The impacted area is less than 2 acres. Although close to Roundup, the site is not completely accessible due to the location next to a sparsely traveled road on the south side of the river. There are no significant hazards at this site, although an existing headframe is an attractive nuisance and could pose a danger to persons playing on or around it. The shaft below the headframe has

recently been covered over by a large concrete slab. There is some scattered debris and a pile of mine waste is located on the opposite side of the road below the old shaft area.

The waste pile is a mixture of sandy and shaley overburden. It does not offer serious problems to vegetation growth and is moderately well vegetated now.

Antelope Mine

The Antelope Mine is located 23 road miles south of Roundup, 1 mile east of the Berten Mine, and has an estimated 5 to 7 acres of impacted area (Map 1). Access to the mine site is provided by one mile of unimproved road leading from the county road out of Roundup. Underground mining ceased in the 1940's.

A large rock ledge overhangs a partially open portal which contains collapsed materials and rock. The rock cantilever is supported in part by a single large post which provides an extremely unsafe condition. The underground workings are partly accessible beyond the portal although the entry is partially blocked. It is overlain by massive sandstone, outcropping for 50 feet above the adit. This sandstone is very competent and shows no weakness. No subsidence was observed in the area. This portal represents a potential safety hazard.

Waste materials found on the steep south aspect are mostly sandy overburden with little or no coal. A small area of burned coal slack appearing as red and gray loams in the bottom of the drainage, is being exposed by erosion of the poorly vegetated overburden. The sandy overburden wastes do not appear toxic but are very erosive and store little water. Runoff from the sandstone slopes above is concentrated on a bench in the middle of the drainageway. Low water holding capacity and the intense radiation of a south facing slope combine to make dessication the major problem for seedlings. Nutrient levels are considered as low as most substratum derived materials found in this area. Unstable slopes pose the major problem to revegetating

this site.

Ponderosa pine and bunchgrasses habitat type dominate the steep slopes surrounding this site. Steepness of these slopes preclude land uses other than habitat for area wildlife.

An old tipple structure is badly deteriorated and is gradually failing presenting another potential safety hazard. Several old structures around the site are in varying states of disrepair and are considered hazardous and unsightly. There is a lot of mining-related debris scattered about the site, and some coal waste piles are present. The safety hazards are significant at this site and should be eliminated despite its remote location.

Johnies Mine

The Johnies Mine is located in the Signal Mountain Quadrangle (section 15, T7N, R26E) about 11 road miles southeast of Roundup (Map 1). It contains over 10 acres of disturbed and mine impacted area. The site is located next to a main county road providing access to several permanent and summer residences.

The adit is caved and a collapsed headframe and shoring complicate access to the portal. The adit strikes south 70° east and inclines approximately 17° downward. A thickly bedded, competent sandstone overlies the adit. No subsidence was seen in association with this adit.

A partially caved shaft is located 100 feet southeast of the adit. It is fenced, measures 8 feet by 8 feet wide, 25 feet deep, and was sunk through a moderately competent sandstone.

Another air shaft is located about 300 feet southwest of the adit. The shaft housing is partially in place and is caved to within 8 feet of the surface. This site is located in a thin to thickly bedded jointed sandstone. Most of the mine structures are in a collapsed condition. A large area of slack exists below the mine near the air shaft.

A fairly large area is covered by nearly pure, loose gravelly and sandy coal with little or no vegetation. Reaction is moderately acidic (pH 5.0-5.5) in the surface but very acidic (pH less than 4.0) at one foot.

A medium size pile of shale-rich waste, which lies near the mine mouth, would have a better revegetation potential. Few problems are associated with the coal-free mine waste as indicated by well-established vegetation.

Surrounding vegetation is representative of the ponderosa pine/ bluebunch wheatgrass habitat type. Cattle were observed at the site indicating its usefulness as summer grazing land.

Safety hazards at this site include the open air shaft, shaft, and adit. The old wooden tipple structure is unstable and unsafe. Access to the area from the nearby county road raises the hazard potential to the public.

Oxbow Mine (Republic No. 4)

The Oxbow Mine is located in Section 17, T8N, R26E, about three miles east of Roundup (Map 1). Workings consist of two adits (one open and one closed), a large production shaft and several depressions which may be subsidence features. The mine disturbance area covers between 10 and 15 acres.

The open adit is 12 feet by 5 feet high, strikes south 10° west, is inclined downward at 10°, and follows a 4 foot thick coal seam several hundred feet into the hillside. The portal and adit are cut in massive sandstone with no sign of stress relief or sagging.

Several depressions are located 110 feet from the portal on a line striking south 36° west. The holes are 10 feet in diameter and one to two feet deep. It was not possible to ascertain with any degree of confidence the association of these depressions.

The second adit is located 50 feet west of the first, at the same elevation. The adit has been closed by boulders, but strikes perpendicular to the first and is ultimately connected with it.

The production air shaft is 12 by 10 feet in plan, 80 feet deep, and is cut in massive sandstone. It is topped by a concrete and timber head frame.

Large waste piles lie on terraces of the Musselshell River downslope from the mine entrance. A slack pile estimated at 15,000 cubic yards is located south of the hay meadow adjacent to a meander bend of the Musselshell River. Nearly all piles are revegetated. Samples from a fine textured black coal waste, an area of scoria or red burned materials and sandstone-rich overburden were taken for analysis (samples 27, 28, 29, respectively, Appendix A). The black waste is moderately acidic (pH 4.3) showing the influence of the coal. Other samples had near neutral reactions. The black material has adequate levels of nitrogen, potassium, and phosphorus for vegetation.

The location of this mine precludes any viable land use other than wildlife habitat and open space. Adjacent alfalfa fields below the mine and rangeland on the bench above have sustained insignificant impacts.

Several old concrete footings and foundations remaining from the old loadout facilities and mine buildings are located at the base of the hillside adjacent to a large hay meadow.

The air shaft is open and accessible, although a wire fence provides some protection against accidental entry. Its accessibility makes it extremely dangerous. The open adit, subsidence features, and remnants of former mine buildings are considered minor hazards.

Jeffries 18 Mine

The Jeffries 18 Mine is located in the Roundup Quadrangle (Section 18, T8N, R26E), at the base of a cliff just across the Musselshell River

from the Roundup Sewage Lagoon (Map 1). The workings consist of an open adit, remnants of an old transportation system which crosses the Musselshell River, several old buildings, and some minor slack piles. Water has partially filled the underground opening. Additional coal slack piles are located to the north, across the Musselshell River.

An adit (4 feet by 15 feet) is located at the base of an 80 foot high cliff of interbedded massive and thinly (one to three inch) bedded sandstone. It extends 30 to 40 feet into the hillside. The sandstone overlying the back is competent and shows no evidence of sagging or failure. There is no evidence of subsidence behind the adit or in the general area. A second adit is located about 600 yards northeast of the first adit. The portal consists of timber covered by an earthen mound. Entry into the adit is blocked by timbers.

The majority of waste materials from this mine now lie on the north bank of the Musselshell River northwest of the mine shaft. This erosive material provides a sediment source to the river as it cuts away the channel bank below the pile. The small pile at the mine mouth is mostly revegetated and contains insignificant amounts of coal. Two large piles to the north are dominated by sandstones and do not appear to have burnable concentrations of coal. Steep slopes and materials with low nutrient or water availability are interpreted to be the main reason for a poor vegetative cover.

Adjacent hayland near the adit appears to be unaffected. Waste materials on the north side of the river do not appear to disrupt potentially irrigable land.

The open adit is considered hazardous whereas other impacts or mine related facilities represent a nuisance or minor hazard.

Number 4 Mine

The Number 4 Mine (Map 1) is located along a county road approximately 5 miles east of Roundup in the Gage Quadrangle (Section 16,

T8N, R26E). The workings consist of a partially caved adit and an open airshaft enclosed by a small concrete housing, both visible from the road. Waste areas lie at the end of a nearly complete tipple, in addition to small slack piles and cabin sites in the area. Total disturbance is estimated to be between 4 and 6 acres.

The adit is partially caved, but still accessible through part of the head frame. The adit, which strikes south, is overlain by a horizontal, thinly bedded sandstone which appears competent on the back and shows only minor sloughing near the portal. The air shaft is located 180 feet, 20° west from the adit. Although it is enclosed with a concrete housing, the shaft is readily accessible, 4 feet in diameter, 40 feet deep and filled with timber. No subsidence features were observed in the area to the south of the mine.

Coal wastes have a pH of 4.0 to 5.5 but are not a large problem due to small volume. The gray shale in the main waste pile has a pH of 8.0 and is expected to be like the Nelson Mine shale wastes.

The open shaft and partially caved adit pose a hazard due to their proximity to the county road and nearby residence. Scattered wood and metal debris are an eyesore next to the highway.

Carlson Mine

The Carlson Mine is located in the Gage Northeast Quadrangle (Section 33, T8N, R27E), on the east fork of Parrot Creek about 6 miles south of Gage (Map 1). The workings consist of a caved adit, an open adit, and a small subsidence hole which could be a caved shaft. These workings have been fenced off by the ranch landowner, John Gebhardt. Mining ceased sometime in 1963. The site contains two to three acres of disturbance.

The adit to the northwest is open and accessible, and is driven in interbedded, thickly bedded, and laminar sandstone which appears strong and shows no signs of sagging. Access to the adit is via a

50-foot long by 8-foot deep trench with very steep sides. The second adit is completely caved. It is located in the same rock type as is the first adit. This adit is accessed by a 60-foot by 10-foot deep trench. Immediately to the north of the first adit is a small circular depression which is 8 feet in diameter and 7 feet deep. This appears to have been a small shaft of some sort. There is no additional evidence of subsidence in the area.

Potential hazards in the area include the unobstructed mine openings, the subsidence hole or shaft, and the scattered mine debris. An intermittent stream flows into the open adit and may be a source of future ground water contamination. No surface water was observed leaving the mine site.

Howard Mine

The Howard Mine is located in the Weed Creek West Quadrangle (Section 3, T8N, R31E) along an isolated draw on grazing land (Map 1). Access is along a jeep trail departing from the unpaved county road leading from Melstone, 8 miles to the north. This site consists of a single open adit and partially closed air shaft. Small amounts of slack lie in the bottom of the gully, through which an ephemeral stream flows. Pine trees and other vegetation are well-established in this material.

The impacted area is small and consists mainly of a 7 foot high by 20 foot wide adit below a massive sandstone. The adit is open and accessible. A 15 foot high by 40 foot long excavation leads into the adit. The adit is overlain by a thick bed of horizontal, massive, very competent sandstone showing no failure on back with the exception of mine exfoliation near the portal. A 4 foot seam of coal is posed along both ribs. No subsidence is evident in the area. The open portal is fairly stable and is not a serious threat to persons and livestock.

RECLAMATION PLAN

TECHNOLOGICALLY FEASIBLE ABATEMENT METHODS

Health and Safety Hazards

The major impacts to health and safety related to abandoned mines in the Bull Mountain Coal Field are open shafts, portals, adits, and Republic No. 3 slack piles. Impacts of lesser significance include subsidence, shallow excavations, old structures, and scattered debris.

Candidate methodologies for closing open portals, shafts, and adits are backfilling and/or sealing with concrete. On-site materials are suitable for fill and concrete can be dry-batched at Roundup and mixed on site. Methods of collapsing tunnels, adits, rooms, etc., include drilling and blasting, dynamic consolidation, and excavation. Demolition and disposal is the only feasible method for eliminating structures and debris. Slack and/or waste piles can be dispersed, amended, and recontoured, or can be removed and wasted elsewhere.

Burning Piles

Burning coal waste piles and mines have presented the greatest challenge to reclamation specialists because of the inherent dangers. Physically moving the pile raises fugitive dust and adds oxygen to the high temperature zones, resulting in a potential explosion. Dousing piles with water adds oxygen to the pile and could cause a steam explosion. Steam explosions have the effect of adding more oxygen, raising fugitive dust levels, which in turn, may result in a dust explosion.

Literature searches and numerous conversations with OSM personnel and other consultants indicate that densification is the best procedure yet developed to solve burning coal waste where temperatures suggest material handling may be dangerous. This conclusion was reached upon review of several test programs, including one recently completed at the

Gebhardt's Post Yard near the Republic #3 site. OSM designed a soil filled trench surrounding the burn area and a fill cover for areal extent. The intent was to deprive the burn of oxygen. The second test site was a burning underground mine and waste piles in western Pennsylvania. Dynamic consolidation (dropping a large mass from a crane repeatedly) was utilized for that project. The mines were collapsed, the waste piles consolidated, and the fire extinguished.

The common denominator for the two, and others in progress, is compaction (consolidation) of the burning or potentially combustible materials. That is, the materials are reduced in volume to the zero air void point.

Subsidence

Subsidence is the enigma of shallow underground mining. Techniques for control and/or elimination of subsidence are varied but generally fall into the categories listed below:

(a) fill subsidence voids as they occur;
(b) destroy pillars and stiff roof section by controlled blasting;
(c) backfill mines either pneumatically or hydraulically with suitable soils or mine wastes;
(d) collapse underground workings through dynamic consolidation techniques previously described.

At this point a brief comparison between dymanic consolidation and blasting is in order. The comparison will provide data on which to assess applicability and practicality.

Dynamic consolidation involves dropping a large mass (25 to 50 ton ingot) from a height of 25 to 50 feet. The mass impacts the ground surface, inducing shear strains and stresses in the roof sections of the mine. The process is repeated until the roof collapses or it becomes apparent that the roof has sufficient integrity to preclude subsidence. Blasting results in high energy forces acting downward to induce shear

stress and strains. The results are immediate if charge size and location are selected properly. Equipment and personnel are available within the state. The system does, however, require detailed knowledge of mine workings and overburden depths.

Dynamic consolidation has several drawbacks for use in subsidence control in the Bull Mountain Coal Field. Mobilization of cranes large enough to perform this work can only be accomplished through extraordinary transportation arrangements, usually by rail. Transportation to the Bull Mountain sites from the nearest point of rail transportation would be difficult, costly, and highly impractical.

Dynamic consolidation is a relatively new concept which, to our knowledge, has never been used in Montana. Very little information is available regarding the success of this method. The only site extensive enough to consider dynamic consolidation is the Roundup Coal Mine site. Equipment of this magnitude cannot, in all probability, be safely used here because the specific locations of abandoned workings are not known, and because of the existing subsidence and ground failure hazards. Additionally, dynamic consolidation, as an abatement method, appears to be excessively costly. Based on a cost of $0.65 per square foot, the costs would be $28,000 to $30,000 per acre.

State-of-the-art technology developed on past and ongoing OSM projects involves exploration drilling, followed by drilling and blasting, to collapse overburden into the underground workings. This is a proven method and is highly appropriate to the Bull Mountain sites. The costs for drilling and blasting, including necessary exploration, are estimated to be in the range of $7,000 to $9,000 per acre, substantially lower than the dynamic consolidation costs. Therefore, we recommend this method for use at the Bull Mountain sites.

The costs of dynamic consolidation appear to be excessive compared to the proven method of drilling and blasting. We believe dynamic consolidation is not viable at the Bull Mountain sites and is not recommended.

Another type of subsidence is associated with mine openings such as shafts and portals. Most shafts and portals can be readily plugged with concrete or controlled fill.

With the exception of two mines (Roundup and Johnson), all subsidence features are associated with very rural and remote sites. Therefore, we conclude that filling of existing subsidence offers the most feasible and cost-effective course of action.

All sites appear to have sufficient and suitable fill materials within reasonable distances of the mines. Remoteness of the mines will, however, add to the unit costs. Cost estimates for planning purposes are included for each site (see site specific plans by site). Detailed estimates will be provided during Phase II.

In order to help establish a priority ranking for filling and to aid in developing a monitoring frequency, we have developed a matrix table for probablity of future subsidence (Table C). Since we do not have time-dependent deformation data for the Fort Union sandstones and coals, we used that presented by Silver, Clemence, and Stephenson (1976). Young's Modulus, E, and Poisson's Ration, U, are summarized below:

Axis	Young's Modulus, PSF	Poisson's Ratio
Vertical	1100	0.2
Horizontal	600	0.4

We suggest that high and moderate probablity mines be inspected twice yearly; low probability mines should be inspected once yearly.

The only high probability sites with respect to subsidence are Roundup and Johnson. Roundup has experienced significant and on-going movement, thereby reducing the agricultural usefulness of the land and endangering the operators. The adit for Johnson appears to pass near a shop building possibly endangering it and adjacent residents.

TABLE C. Probability of future subsidence.

MINE	LOW	MODERATE	HIGH
Nelson	X		
Keene 26		X	
Carpenter	X		
Nies		X	
Square Deal	X		
Johnson			X
State Section 16	X		
Keene 28	X		
Jeffries 4	X		
Cooper	X		
Western	X		
Roundup Coal			X
Republic No. 3	X		
Berten		X	
Musselshell	X		
Antelope	X		
Johnies		X	
Oxbow	X		
Jeffries 18	X		
Number 4	X		
Carlson	X		
Howard	X		

Soils and Related Problems

Based on field observations and laboratory data, the problems from coal-rich mine waste materials are primarily related to: 1) potential destruction of root medium by fire, and 2) moisture, temperature, and nutrient stress. Other materials with little or no coal have problems for plant establishment from moisture, nutrients, and in some cases mechnical impedance. Reclamation techniques will be addressed by major type or problem.

Fire Hazard Reduction

Waste piles composed of fine grained coal rich in pyritic sulfur and exposed to abundant oxygen, precipitation, and a heat source have a potential for spontaneous combustion. Most slack coal piles in the Bull Mountain study area are generally coarse grained except where equipment traffic has crushed the coal. Pyritic sulfur is present but because most coal piles have been exposed to weathering for some time, the sulfur has already been oxidized and is now in sulfate forms or has been leached away. The surfaces of the coal piles are exposed to adequate oxygen to encourage rapid oxidation. The major heat source to these piles is the sun but may also include range fires or coal fires. Most coal piles do not have the right combination of factors to carry heat producing oxidation rates to the point of spontaneous combustion. Range fires are a significant heat source which have started coal fires in the past.

Eliminating the fire hazard from coal piles in the Bull Mountains should be done by removal of the pile and burial to remove the major sources of heat. Removal of air and water is desireable but probably not essential owing to the already oxidized nature of coal in the area. Dilution of small quantities by mixing with local soils is another possible alternative in many areas with small piles.

Costs are primarily associated with equipment needed to dig, bury, or for spreading coal waste material.

Improving the Physical Condition of the Seedbed

Coal: Seedling dessication as a result of low water holding capacity in coal waste piles is considered the main reason for lack of natural revegetation of these areas. This is compounded by the lack of water in a climate such as the Bull Mountains with high potential evaporation and by the high temperatures created by the low solar reflectance inherent in coal waste piles.

Mixing light colored loamy textured native soil with coal will increase water holding capacity of the surface rooting zone and increase soil reflectivity. Straw mulch spread and crimped into the ground will provide additional reflectivity needs as well as increase organic matter levels for nutrient and water holding properties.

Costs expected for these treatments are approximately \$300/acre to mix coal and soil and about \$500/acre to spread and crimp straw.

Shale: Root penetration is inhibited in shale rich wastes which have been compacted by heavy equipment operation. The primary example of this type of compaction is seen at the Republic No. 3 Mine on the east end of the main waste dump. Water infiltration is also reduced by compaction. This reduces water availability for plant use and for leaching of salts out of the waste material. Infiltration can be increased and root growth enhanced by a combination of mechanical surface manipulation and use of proper amendments. Severe or deep compaction will require the use of deep ripping equipment such as a cat tractor ripper. Where compaction is not as severe, a chisel plow should be used to break up the upper foot for root penetration. Infiltration can also be increased by creating depressions with either dozer basins or gouging (Dollhopf and Goering, 1980). Organic matter can increase soil friability and encourage root growth. Straw or other source of organic matter should be incorporated into the upper six inches and if possible in the upper foot. The SAR was not high in Bull Mountain shales so treatment of sodium problems to improve the physical condition is not needed.

Cat tractors used for ripping and other surface treatments cost about $150/acre for each step in the process used. Straw mulch application will be less since crimping is replaced by mixing and will be included as part of the liming operations.

Improving the Chemical Condition of the Seedbed

Neutralization of Acidity: Coal piles sampled were nearly all moderately acidic with an average pH for pure coal slack of 4.9 (Table 5, Appendix A). Mixing with other wastes such as occurs at the Republic No. 3 Mine can raise the average pH to 6.0. Only a few shale-rich gob piles have very acidic reaction. Examples include the Keene 26 and Berten mine spoils with average pH's near 2.9.

Problems with availability of nutrients at low pH will be resolved by raising the pH to 6.5 to 7.0. Lime is the standard method of increasing the pH of agricultural soils and has been used in treatment of acidic mine wastes. Native soils are normally alkaline to slightly alkaline within the low precipitation zones such as found in the Bull Mountains. Since native soils will be mixed with coal for various purposes within this plan, they have also been analysed for their ability to neutralize acid. Lime requirements are based on an Acid-Base analysis from both wastes and native soils.

The greatest lime needs are for acidic shales at the Keene 26 Mine where 16 tons of lime/1000 tons of waste are needed to reach neutrality (Table D). Soil derived from Musselshell River alluvium at the Roundup Mine is rich in calcium compared to soils derived from Fort Union formation materials. Roundup Mine area soils have a neutralizing capability comparable to nearly 100 tons of lime/1000 tons of soil. Six inches (1000 tons) of that soil could neutralize about three feet of acidic shale. Local soils such as those near the Roundup Mine appear a feasible alternative to lime if the waste can be spread and thoroughly mixed with soil.

The lime to be used should be pure calcium carbonate or an equivalent

TABLE D. Liming needs for Bull Mountain waste materials.

				ACID-BASE ANALYSIS					
Material	Samples	Average pH	Estimated CEC[1]	Total S	Sulfate S	Pyritic S	Organic S	Neutralization Potential	Acid Base Potential[2]
Pure Coal	2*,3,4,5, 6, 26, 30, 31	4.9	20	0.49	0.05	0.01	0.43	1.89	-11.89
Mixed Coal	7, 8*, 9, 10 27	5.2	25	0.51	0.18	0.10	0.23	4.50	-5.81
Acidic Shale	22, 23, 24, 25*	2.9	40	0.80	0.42	less than 0.01	0.38	-4.70	-16.57
Musselshell Soil		7.4		0.01				99.7	99.4
Fort Union		7.5		0.01				32.7	32.4

[1] CEC = cation exchange capacity (me/100g) based on estimated clay type and amount.

[2] Units are tons lime needed/1000 tons material or tons/acre furrough slice (6 inches deep)

* Sample used for acid-base analysis

form that is ground so that 90% passes a #10 seive (less than 2mm). The material used should be spread and thoroughly mixed with the upper six inches to a foot of material treated. For proper action of the lime, there should be some time before fertilizer or seed is applied to the site. Six months is desireable but a week or two is acceptable. The cost of lime delivered to the site is estimated at $90/ton. Spreading costs are estimated at $50/acre and mixing at $150/acre.

Fertilization: Fertility ratings for materials in the Bull Mountains are based on measurements of nitrate nitrogen, available phosphorus, and extractable potassium. Organic matter content is another indication of nitrogen available in the system and shows long term availability. Average soils of the Yellowstone drainage have 3% organic matter (Muir, 1979). Nitrogen levels are considered adequate if nitrate nitrogen levels are more than 15 parts per million (ppm) (Berg, 1980). Available phosphorus is low if values are less than seven ppm (Berg, 1980; MSU, 1972). Potassium levels of 160 ppm are considered adequate (Chapman, 1966). Even though a response to potassium fertilizer is not seen for rangeland species (MSU, 1973) grasses and small grains begin to need potassium when values are less than 125 ppm (MSU, 1972a, 1972b). Ratings of fertility level are recorded in Table E. The amount of fertilizer needed to adjust the material to desired levels is calculated for each major type of material tested in the Bull Mountains area (Table E). Fertilization rates are based on guides for small grains and are expressed in pounds/acre of elemental nitrogen (N), phosphorus as phosphate (P_2O_5) and potassium as potash (K_2O). Many sites in the Bull Mountain Coal Field require similar amounts of each fertilizer element so for prescription purposes three basic rates are proposed (Table F). Most soils and non-acidic waste require only nitrogen and phosphorus (50-15-0). Application rates calculated from nutrient analysis were adjusted upward to compensate for the addition of straw mulch (Treatment C, Table F). Acidic materials had more straw prescribed and usually had low potassium levels. An application rate of 70-150-40 is prescribed for these materials (Treatments A and B, Table F) to adjust for additional mulch and lower potassium levels.

TABLE E. Fertilization needs of materials at the Bull Mountains Coal Field.

Amount Present and Rating
VL = very low
L = low
M = medium
H = high
VH = very high

Number	Material Type	Samples Represented	Organic Matter (%)	N03-N ppm	Phosporus ppm	Potassium ppm	Fertilizer Needs*		
							N	P_2O_5	K_2O
1	Pure Coal	2, 3, 4, 5, 6, 26,30,31	32.3 VH	7.9 L	1.6 VL	64.6 L	50	100	40
2	Mixed Coal	7, 8, 9, 10,	14.1 H	5.7 L	1.8 VL	184.0 M	50	125	-
3	Burned Coal	28	0.0 VL	1.3 VL	7.1 V1	144.0 M	80	100	-
4	Neutral Shale	1, 11, 12, 13, 14	11.1 H	10.2 L	0.5 VL	138.0 M	50	200	-
5	Acidic Shale	22, 23, 24, 25	20.5 VH	6.2 L	0.6 VL	25.5 L	50	200	40
6	Non-coal gob piles	29, 32	0.1 VL	13.5 M	1.3 VL	554.0 H	30	150	-
7	Local soils plus substrates	15, 16, 17, 18, 19, 20, 21	-	3.4 L	3.6 VL	129.0 M	50	150	-

* Pounds of each fertilizer needed in an acre.

Table F. Standardized seedbed preparation for major materials of the Bull Mountains Coal Field.

Materials	Cost (Dollars/Acre)
A. Acidic Coal Slack Piles	
Spread coal to one-half foot and/or bury	200.00
Add lime @ 5 tons/acre @ 85.00/ton + 50.00/acre	475.00
Apply fertilizer (70lb/a N - 150lb/a P_2O_5-40lb/a K_2O) @ 86.00/acre + 30.00/acre	116.00
Mix above amendments with top 6" of mineral soil	150.00
Spread and crimp straw mulch @ 1½ tons/acre	500.00
	$1441.00
B. Acidic Shale Gob Piles	
Rip to 2' to break up compaction	300.00
Create surface depressions as specified	200.00
Loosen surface 12" with chisel plow	100.00
Apply lime @ 17 tons/acre + application costs	1495.00
Apply fertilizer (70-150-40) @ 86.00/acre + application costs	116.00
Thoroughly mix mulch @ 1 ton/acre to 12"	150.00
Mulch @ 1 ton/acre spread and crimped	500.00
	$2861.00
C. Neutral Loamy Gob or Overburden	
Surface graded to less than 3:1 slope	200.00
Fertilizer (60-150-0) @ 80.00/acre + application	110.00
Mulch @ 1 ton/acre spread and crimped	400.00
	$700.00

Standard Treatments

A unit cost of various treatments is presented in Table G which is used to calculate the cost of each of the standard treatments listed in Table F. Adjustments to the standard treatments will be proposed in the section in Site Specific Plans by Site.

Revegetation

Technologies are available to establish a permanent vegetative cover on abandoned mine sites. Aldon (1978) and Brown and Johnson (1978) have outlined the steps necessary for successful land rehabilitation. These apply to revegetation of the coal spoils found in the Bull Mountain Coal Field. The first of these is a clear determination of the objectives of the reclamation project. In this case, the objectives of revegetation are to deter overland flow and subsequent surface erosion, to provide an oxygen barrier so that oxidation of pyrites is minimized (Richardson and Farmer, 1981), and to restore the productivity of the sites in a way compatible with the desired land use. The next step involves shaping and grading of the site to blend in with the surrounding landscape, to control water runoff, and to be compatible with the projected land use (Harwood, 1979). Slopes in excess of 30° may be difficult and expensive to revegetate. Further steps specific to revegetation include choosing appropriate soil amendments, fertilizer, topsoil, suface mulch, adapted plant species, planting season, and planting techniques.

Harwood (1979) indicated that topsoiling is usually required for successful revegetation of abandoned mines wastes (see Soils discussion). Bradshaw (1980) noted that topsoil contains seed and vegetative propagules which may greatly enhance the revegetation process. McAllister (1981) reviewed many studies in which topsoiling was found to aid plant establishment and to provide a source of rhizomes, seeds, and root material. Harwood (1979) pointed out that the topsoil selected for a given site should closely approximate that found on adjacent undisturbed land. Generally, the topsoil should be

Table G. Cost to treat materials at the Bull Mountains Coal Field.

Treatment	Cost (Dollars/Acre)
Mechanical Manipulation	
Ripping compact shale-cat tractor	300.00
Gouging and dozer basin-cat tractor (1/3 acre/hour)	200.00
Spreading coal or other material-cat tractor	200.00
Mixing amendments or wastes-mulboard plow	150.00
loosening compact soil-chisel plow	100.00
Amendment Application	
Straw mulch-spread and crimped-serrated disk (1 ton/acre)	500.00
Wood fibre mulch-hydro mulcher	700.00
Fertilizer-broadcast	30.00
Lime-broadcast	50.00
Amendment-Materials Costs	
Lime-coal @ 85.00/ton x 12 tons/acre	1070.00
Lime-acidic shale @ 85.00/ton x 17 tons/acre	1445.00
Fertilizer-acid material	86.00
Fertilizer-neutral material	80.00

selected for its texture, available water holding capacity, organic content, workability, spreadability, and tilth. The depth of topsoil recommended for successful revegetation varies widely in the literature. Harwood (1979) indicated that the topsoil depth must be adequate to support full development of the roots of seeded species. Topsoiling can be quite expensive and transportation of topsoil to the site is sometimes a problem (Bradshaw, 1980). Bradshaw (1980) presented several alternatives to topsoiling including application of sewage sludge, peat, mushroom compost, and farmyard manure. Sewage sludge is one of the best alternatives since it has good structure and nutrient content. The organic matter also provides for slow continuous release of nutrients. Sewage sludge provides a buffer against toxic metals because most metals are complexed and rendered innocuous by organic matter.

McAllister (1981) reviewed several studies evaluating the use of various surface mulches in revegetation. Mulching with standing stubble of small grains (e.g. wintergraze, barley) has been quite successful because the root production provides for soil stabilization. Crimped straw has also been quite successful. Native hay mulch has value because it is a source of native plant seed. Hydromulching with wood fiber is recommended for steep slopes inaccessible to heavy equipment.

Species used in revegetation must be adapted to the climate and soils of the area and be compatible with the desired land use. The amount, form, and seasonal distribution of precipitation are critical to species selection because moisture is normally the limiting factor for plants in semiarid regions (Institue for Land Rehabilitation, 1979). Legumes should be included in the seeding mixtures to provide a continuous source of soil nitrogen (Bradshaw, 1980).

The season of planting should generally preceed the longest period of favorable growing conditions (Vallentine, 1980). In the Bull Mountain Coal Field, this would be done in the fall.

Late fall seedings are recommended for this project because seed dormancy and germination requirements of the cool-season grasses will

be met during the winter, and the subsequent early spring germination will precede the most favorable soil moisture conditions.

Seeding methods available include drill and broadcast seeding. Drill seeding favors larger seeded species because it places seed uniformly at a specified depth while broadcast seeding favors a variety of species because seeds are placed at different depths and in different microsites (Vallentine, 1980). Drilling will be done for this project where slope and topography permit because of generally better establishment with this method. Drilling results in even distribution of seed and assures good contact of seed with the soil. Broadcast seeding is quite versatile because it can be done by hand (Cylcone Seeder), by machine (Brillon Seeder-Packer), and on very steep slopes (Hydroseeder). Broadcast seeding will be done on steep slopes (greater than 3:1) and very small areas.

The species selected for use in revegetation were based on vegetation occurring naturally adjacent to the abandoned mine sites. Value in soil stabilization and projected land use were also considered. Four seed mixtures were formulated (Table H) to revegetate upland grasslands, irrigated hayland, and drainageways. The Upland Grassland mixture includes relatively few species both for economy and to assure rapid site stabilization. Diversity will be achieved as propagules from adjacent plant communities invade the sites. The Irrigated Hayland seed mixture will produce a grass-legume hay similar to that found on haylands in the Roundup area. Species used in the Grassed Waterway mixture were chosen for their value in site stabilization and tolerance to periodic flooding and siltation. Legumes have been included in all mixtures to assure a continuing source of soil nitrogen.

Seed used for revegetation should have the highest purity and germination rates available. Seed sources have been presented by McAllister (1981) and Westech/Hydrometrics (1982). Seed should be obtained from sources within 300 miles north or south of the study area and 500 miles east or west (USDA-SCS, 1976). Legume seed must be inoculated with the appropriate rhyzobium so that nitrogen fixation is

TABLE H. Seed mixtures and planting rates for revegetation units.

Revegetation Unit 1 - Upland Grassland

Species	Variety	Seed Mixture (lbs PLS/acre)	PLS/ft²
Alternative A (bunchgrass dominated mixture)			
Beardless wheatgrass	Whitman	5.2	15.0
Western wheatgrass	Rosana	2.8	7.0
Indian ricegrass	Paloma	0.9	3.5
Little bluestem	Blaze	0.6	3.5
Cicer milkvetch	Lutana	1.0	3.0
	Totals	10.5	32.0
Alternative B (sod forming grass mixture)			
Western wheatgrass	Rosana	5.6	15.0
Green needlegrass	Lodorm	2.1	8.0
Blue grama	lovington	0.5	7.0
Cicer milkvetch	Lutana	1.0	3.0
	Totals	9.2	33.0

Revegetation Unit 2 - Irrigated Hayland

Species	Variety	Seed Mixture (lbs PLS/acre)	PLS/ft²
Alfalfa	Promor, Anchor Apollo, Thor	3.8	18.3
Intermediate wheatgrass	Amor, Greener	5.6	12.0
	Totals	9.4	30.3

Revegetation Unit 3 - Grassed Waterway

Species	Variety	Seed Mixture (lbs PLS/acre)	PLS/ft²
Streambank wheatgrass	Sodar	6.0	22.0
Western wheatgrass	Rosana	6.0	15.2
Cicer milkvetch	Lutana	1.0	3.0
	Totals	13.0	40.2

maximized.

Seedbed preparation will be done as soon as possible following placement of topsoil, addition of amendments, and fertilization. The seedbed should be chisel-plowed or disced, and harrowed to eliminate clods and produce a firm, smooth surface. Steep slopes, requiring broadcast seeding, may be left with a more irregular seedbed to prevent soil movement and to provide a variety of microsites for germination. A weighted spike harrow effectively prepares such slopes for seeding.

Seeding will be done using hand seeders, hydroseeders, a Brillion grass seeder, or a grass drill, depending on the size and slope of the area. On slopes not exceeding 3:1, a drill or Brillion seeder is recommended to maximize seed contact with the soil and evenness of planting depth and distribution. Drills should be equipped with agitators, depth bands, a seed-metering device, and packer wheels. One-half ton per acre of straw mulch or native hay will be applied over the seeding and crimped into the soil. Steeper slopes should be broadcast seeded by hand or with a hydroseeder. Seed will be covered by harrowing if possible and mulched with one ton per acre of straw or native hay. Mulch may be anchored with netting or chemical tackified on very steep slopes or one ton per acre of forest fiber mulch may be applied with a hydraulic seeder-mulcher.

Revegetation Unit 1 - Upland Grassland

Two alternatives have been chosen to accomodate soil differences between sites in the eastern and western portions of the study area. The bunchgrass mixture (Alternative A, TABLE H) is designed for sandier sites in the ponderosa pine dominated western part of the Bull Mountain Coal Field. Species chosen for revegetation in this unit include beardless wheatgrass, little bluestem and western wheatgrass. They are designed to approximate the major dominates found in surrounding undisturbed areas. Indian ricegrass occurs naturally in the area and has value for rapid soil stabilization. Ponderosa pine should reinvade reclaimed sites rapidly. Cicer milkvetch, a legume, will

provide a steady source of soil nitrogen.

Alternative B (TABLE H) is chosen where surface soils are rich in silts and clays. The rhizomatous nature of these species makes them well suited for these areas.

Seed will be drilled on slopes less than 3:1 after preparation of a firm, weed-free seedbed in which fertilizer has been incorporated. Planting depth will be one-half inch. Drilling will be done on the contour. Legume seed will be planted in separate rows from the grasses. Sites will then be mulched with one-half ton per acre of straw or native hay.

Seed will be broadcast on slopes greater than 3:1. The seedbed may be left in a roughened condition so that natural sloughing covers the seed. If possible a harrow will be used to cover the seed. The seedbed will then be mulched with one ton per acre of straw, native hay, or wood fiber, anchored with netting or a chemical tackifier.

Revegetation Unit 2 - Irrigated Hayland

The grass-alfalfa mixture has been designed for these areas because this mixture appears to be the preferred hayland mixture growing in the Roundup area. Where desired, the grass component can be substituted by increased alfalfa seeding (one and a half times). This crop will usually produce the highest yield of highest quality hay when grown alone.

Seed will be drilled on the contour following preparation of a firm, weed-free seedbed and incorporation of fertilizer. Seeding depth will be one-half inch for the grasses and one-quarter inch for the alfalfa. Alfalfa seed will be planted in separate rows. One-half ton per acre of straw mulch will be applied following seeding. An initial crop of barley can be used rather than straw mulch. Following harvest, seeding will be applied directly into the grain stubble.

Revegetation Unit 3 - Grassed Waterway

Species in this mixture were chosen for their value in site stabilization and resistance to siltation and grazing.

Seed will be drilled on slopes less than 3:1 into a well-prepared seedbed. Drilling will be accomplished in two phases. The first will be on the contour at half the seeding rate and the second at an angle to the first at half the seeding rate. The seeding will then be mulched with one-half ton per acre of straw or native hay mulch.

Seed will be broadcast and mulched on steeper slopes as described for the Upland Grassland mixture.

Cost estimates for all direct and associated revegetation efforts are found in TABLE I.

It is important to evaluate seedling success and intercede if failure is a possibility. A regular monitoring program should be set up to judge the effectiveness of seeding efforts. Soil analyses are also a necessary part of a monitoring program to ensure successful revegetation. Periodic soil monitoring will identify possible sources of seeding failure such as acidification, leaching, and soil moisture problems.

The presence of lush vegetation on revegetated areas will attract wildlife. Provisions need to be made to restrict wildlife use. This can be most effectively accomplished through the use of big game proof fence around reseeded areas.

Wildlife enclosures should remain in place three to five years to ensure adequate time for stabilization. On steep slopes where shrubs and trees are to be planted, a five year minimum is necessary before grazing by cattle or wildlife is permitted.

Specific methods of evaluating seedlings are given by Vallentine (1980) and the Interagency Forage, Conservation, and Wildlife Handbook

TABLE I. Revegetation cost estimates for the Bull Mountain Coal Field sites.

Treatment	USDA-SCS and OEA Research Estimate (per acre basis)
Seedbed preparation	$21.00
Seed	90.00 maximum
Seeding (drilled)	30.00
Seeding (broadcast)	45.00
Mulch	25.00 (straw)
Fencing	475.00-550.00
Maintenance (add 20%) 3-5 years	128.00-146.00
TOTAL	769.00-913.00

(1977). The following criteria for evaluating the seedlings are appropriate to the study area: good (more than one seedling established per square foot); fair (0.5 to 1 per square foot); poor (less than 0.5 per square foot).

Nielson and Peterson (1972) presented the following method of revegetating mine spoils which is compatible with the above review:

(a) Obtain a representative sample of the spoils and test for pH, salinity, electrical conductivity, nitrogen, phosphorus, potassium, and sulfides. This yields information on salinity, acidity, fertility, and acidifying potential. If the pH is less than 6, liming will be required. All sites should be fertilized with material and rates based on the soil test.

(b) Topsoil the site if possible and prepare a good seedbed.

(c) Select hardy species for revegetation.

(d) Control wind erosion with mulches, binding agents, or mechanical barriers such as snowfences.

Stream Channel Impact Reclamation

Streams and drainages impacted by mine dumps and/or coal slack will necessarily require some form of reconstruction to maintain drainage integrity and to provide for a successful reclamation program. The types of impacted channels evaluated in this study are predominantly ephemeral. Given this, the following presents general techniques for ephemeral channel reconstruction which are applicable to the Bull Mountains area.

Channel reconstruction will typically coincide with other land-shaping reclamation activities. The critical features in the design and construction of ephemeral channels are channel shape, size, and gradient suited to a given construction material, and drainage area. Other factors that must be detailed include design-storm runoff events, channel vegetation, and armoring. Implementation of these considerations in concert should aid in reconstruction of a viable, areally compatible drainageway.

Generally, wide, shallow channels are necessary to retard stream velocities and erosion on unvegetated areas (Haan and Barfield, 1978). This is to account for allowable velocities and tractive forces inherent to surface water erosion. If the channel can be protected from erosion, allowable velocities can be increased resulting in deeper and narrower channels. This channel protection can be accomplished by utilizing vegetation or by armoring the channel with non-erosive, coarse material.

The type of vegetation reestablished in a channel is important in determining the degree of control provided for a given runoff velocity. With proper seed mixtures, based on quantified retardance classes, erosion of channel slopes of ten percent and less can be effectively controlled (Haan and Barfield, 1978).

Another option in protecting regraded channels from scour and subsequent sedimentation is lining the channels with non-erodible material, or rip-rap, with provisions made for a drop structure at the terminus of the construction. The type of lining is dependent on drainage area, grade, and design-runoff values (Chow, 1964). With proper construction techniques, channel lining can act to effectively dissipate energy from runoff events and provide for successful reclamation.

Several mine disturbance areas are located near drainage divides where the drainage areas are small. Reconstruction of drainages at these locales will involve smoothing the topography into a form conducive to runoff from the site and blending the reconstruction into any existing drainageways. Erosion and sedimentation are not expected to be a problem near drainage divides; thus, the level of specificity as to engineering design for channel reconstruction will be less.

SITE SPECIFIC PLANS BY SITE

Nelson Mine

Reclamation needs at this site include filling of subsidence features, portal blocking, and trench backfilling. Since the mine is immediately adjacent to the county road, a clear hazard is presented. Therefore, the following recommendations are presented.

(a) Seal the portal with on-site material to plug the opening.
(b) Fill all subsidence features with on-site soils. The fill should be mounded to six inches above adjacent grade.
(c) Backfill the access trench with on-site soils. Again, the fill should be mounded to six inches above the adjacent grade.
(d) Use seedbed preparation A (Table G) without the addition of lime.
(e) The grassed waterway seed mixture (Table H) should be used at this site.

All reclamation work at this site can be readily accomplished using conventional construction methods and equipment. Reclamation costs are estimated at $4,000 to $6,000.

Keene No. 26 Mine

The Keene No. 26 Mine has a mine drainage problem which pollutes a small water course below the portal. Therefore, reclamation appears appropriate. Recommendations are as follows.

(a) Fill all subsidence features, except that behind the portal, with on-site soils. The fill should be mounded to six inches above adjacent grade.
(b) Construct a shotcrete (gunite) seal to close the entrance to the existing concrete portal entry. Provision will be made for a suitable subdrain to carry the mine discharge to the creek. Backfill overlying the shotcrete seal should consist of neutralized coal slack or waste dump material. Concurrent with the backfilling process, compaction will be completed on each "lift" to promulgate a stable, reclaimed landform.

(c) Subtle topographic modifications to direct runoff, or actual diversion ditches may be constructed. The theory in utilizing these techniques is to route runoff and sheetwash from undisturbed lands around the areas of disturbance thereby decreasing the potential for surface water contamination from these sources. With implementation of the necessary diversion, the source area for runoff and subsequent erosion is reduced to the disturbed site itself. The tipple and other structures should be demolished and buried along with all other debris and scattered trash.

(d) Use seedbed treatment B (Table F) with the possible reshaping of the surface and spreading the gob pile over native soil.

(e) The Grassed Waterway (see TABLE H) seed mixture should be used adjacent to the stream. Adjacent upland areas should be seeded with the Upland Grassland Alternative A mix (see TABLE H).

Reclamation costs for the Keene No. 26 are estimated at $35,000 to $40,000.

Carpenter Creek Mine

Reclamation at the Carpenter Mine will consist mainly of site cleanup. Standard construction equipment and methods are recommended for the demolition and burial of structures and concrete foundations, and collection and burial of debris. Use the seedbed treatment A without liming (Table F). The area should be seeded with the Upland Grassland Alternative B (see TABLE H) seed mixture. Costs are estimated at $6000 to $8000.

Nies Mine

The site will require sealing two adits and a shaft, removing existing structures, and cleanup. Recommendations are presented below.

(a) Seal open portal at Mine No. 1 with shotcrete.

(b) Seal both portals with on-site material.

(c) Seal shaft. Backfill with wastes and cover with concrete cap.

(d) Fill all subsidence features with on-site soils. The fill should be mounded six inches above adjacent grade. Access trenches should be backfilled in a similar manner.

(e) The dump should be backfilled as in (c) above. Slack or waste can be used for the bottom five feet, if desired, provided it is compacted to near zero air void condition. The upper two feet should be on-site soils.

(f) Disposal of combustible materials should be by burning or burial since off-site disposal is not feasible.

(g) Use the seedbed treatment A give in Table G.

(h) Seed with the Upland Grassland Alternative A (Table H) seed mixture.

Costs are estimated at $19,000 to $24,000.

Square Deal Mine

The Square Deal site requires removal of ruins and cleanup. Debris and scattered trash should be collected and buried and the waste and slack piles leveled and contoured. The area in front of the former adit should be backfilled with on-site waste and recontoured. The metal framework above the concrete covering the adit should be dismantled and buried.

Liming in conjunction with seedbed treatment A should be used at this site. The area should be seeded with Upland Grassland Alternative A (see TABLE H) seed mixture.

Reclamation costs are estimated to be $10,000 to $12,500.

Johnson Mine

The hazards at this site warrant attention because of the county road, a shop adjacent to the road, and a nearby residence. The following

recommendations are presented.

(a) Collapse all workings extending in a westerly direction from the portal. The north-south limits are defined by the extent of existing subsidence feature. A drilling and blasting program should be implemented to stabilize the subsidence area. The necessity of shop removal should be evaluated before any blasting is performed.

(b) All voids left by collapse should be filled with on-site or locally available borrow. The ramp pile can be used for fill, provided it is placed at the bottom of the void. Grade the new surface to provide positive drainage away from the work area.

(c) The access trench should be backfilled as in (b) above.

(d) Use seedbed treatment C (TABLE F) but without any mechanical treatment of the sandy wastes.

(e) Seed with the Upland Grassland Alternative A (see TABLE H.) seed mixture.

Reclamation costs are estimated at $30,000 to $35,000 assuming relocation or removal of the shop building will not be necessary.

State Section 16 Mine

Some reclamation work has previously been done at this site. Two shafts remain to be sealed. The open shaft should be closed using a cast-in-place reinforced concrete cover. The other shafts can be cleaned out and backfilled using material from the large waste pile. A large pile of rock and dirt should be removed and dispersed. Use of conventional equipment is recommended.

The area left by the removal of waste material should be prepared for seeding using Treatment A (TABLE F) without liming and then seeded with the Upland Grassland Alternative A (see TABLE H) seed mixture. Removal of the coal may be difficult to do without damaging the large trees and impossible to do without killing many small trees. A stable vegetative cover is expected to have no trouble establishing itself.

Costs are estimated at $10,000 to $12,000.

Keene No. 28 Mine

Proximity to residences and the resulting threats from open shafts and portals determine reclamation at this site. The following procedures are recommended.

(a) Closure of open portal with on-site materials at least five feet beyond the entrance. Existing waste piles should be backfilled into the excavation at the mouth of the portal.

(b) Seal the existing shaft with a concrete apron. A hatch with locking mechanism should be provided to allow access by the owner.

(c) Remove concrete footings and other debris.

(d) The use of a specific waste treatment technique is not possible at this site. Rather, waste material should be removed and the remaining steep slopes stabilized using a hydroseeder and the following seed mixtures.

(e) The Grassed Waterway (see TABLE H) seed mixture should be used here in the small coulee and the Upland seed mixture on the sideslopes.

Conventional construction methods and equipment are recommended for all reclamation efforts at this site. The reclamation cost is estimated at $13,000 to $15,000.

Jeffries No. 4 Mine

Reclamation of the Jeffries No. 4 consists of closing four adits and site cleanup. The adits can be sealed by covering the portals with on-site waste materials and regrading or can be collapsed using permissible explosives. Burial of trash and debris and the leveling of the waste pile can easily be accomplished using standard construction equipment.

Seedbed Treatment A (TABLE F) using one-half the lime rate is recommended here. The Upland Grassland Alternative A (see TABLE

H) seed mixture should be seeded at the site.

The estimated costs of reclamation are $13,000 to $15,000.

Cooper Mine

The proximity of the adit to U.S. Highway 87 and the relative simplicity of reclamation indicate the site should be reclaimed. Recommendations follow.

(a) Seal the open adit with shotcrete.

(b) Regrade and excavate surrounding disturbances.

(c) Fertilize at rates in treatment (TABLE F) and seed with the Upland Grassland Alternative A (see TABLE H) seed mixture.

The cost of closing the portal and associated work is estimated at $1,500 to $2,500.

Western Mine

This mine is currently in use as a mushroom plantation and will be for the foreseeable future. The second, unused adit is partially collapsed and should be reclaimed; the owner has already indicated it will be. We present the following recommendations.

(a) The unused adit should be reestablished with the entry stabilized using a 36 inch culvert with the open end secured by a locking cover.

(b) All unused shafts and voids should be filled with on-site soils graded to provide positive drainage.

(c) The owner wants to retain most of the buildings on the site; demolition is required only for the tipple, the structure over the air shaft, and the rock ruin. The combustible materials from the demolition can be burned or buried, and debris can be collected and buried.

(d) Earth and rock from the tipple ramp and slack and waste piles can be leveled and contoured with equipment. Coal waste piles should be graded out down the slope and topsoiled

or topsoiled in place. Contouring will alleviate the steepness of these waste areas. The area should be prepared for seeding using Treatment A (TABLE F). The Upland Grassland Alternative A (TABLE H) seed mixture is to be seeded on this and other disturbance areas.

Estimated costs are between $21,000 and $26,000.

Roundup Mine (Williams and Davis Mines)

Roundup Coal presents a classic subsidence study. Overburden is thin, horizontally bedded and weak, and mining is extensive. Land use is agricultural but cannot continue into the future because of the subsidence. Reclamation is a high priority. Recommendations follow.

(a) The adit should be blasted shut using conventional explosives.

(b) Topsoil should be salvaged and stored according to textural guidelines specified. In general, loamy textures should be separated for the final lift. Sandy textures are suitable for initial fill. Gravelly textures are not suitable for salvage.

(c) The approximately 23 acres of subsidence should be collapsed using exploration drilling followed by drilling and blasting as developed by OSM for such applications.

(d) The resulting voids should be backfilled with coal slack from the Republic No. 3 dump and be compacted. The top two feet of fill should be on-site or locally available borrow. Grading should provide positive drainage away from the work area. Coal slack should be evaluated for pollution and environmental degradation potential prior to use.

(e) The air shaft should be backfilled with on-site or locally available borrow.

(f) Subsidence in adjacent areas should be monitored by air-photo analysis.

(g) The ephemeral drainage located east of the subsidence features has been disturbed by high velocity water discharged from the Republic #3 Mine. Subsequent to removal

of the waste material, a compound channel should be reconstructed to safely pass design runoff events. The compound channel will consist of an active V-shaped channel capable of containing a 2 year, flood event. The active portion of the channel will be flanked by a reconstructed surface capable of safely passing the 100-year, 24-hour design runoff event. Using the channel design criteria described above, the disturbed portion of the channel will be blended into the existing undisturbed channel reaches to provide for a smooth transition.

(h) Following site stabilization, the entire area should be graded such that the two to four feet of topsoil material on the site is equally distributed and the area leveled with positive drainage toward the Musselshell River. Manure is recommended as a fertilizer because of its soil-building properties. A rate of two tons per acre will provide adequate soil nutrients.

(i) The Irrigated Hayland (see TABLE H) seed mixture should be applied. Only SCS approved irrigation practices are to be allowed on these field to reduce future unanticipated subsidence activities.

Costs for reclamation are estimated at $460,000 to $500,000 which does not include costs of removing the material from Republic No. 3 and transporting. These costs are more properly associated with reclamation of the Republic No. 3 site.

Republic No. 3

This study area presents the greatest safety hazard of all sites. Burning coal waste piles and the threat of spontaneous explosion are the major hazards. If the Roundup Mine is reclaimed, all of Republic No. 3's coal waste will be used as fill. Tests indicate they can be safely removed. Based on this scenario, the following recommendations are presented.

(a) Remove all coal wastes to the Roundup Coal Mine for use as

fill on that site's subsidence areas.

(b) A compound channel should be reconstructed following slack pile removal to reconstitute the original ephemeral channel which exists there. The channel will consist of an active v-shaped feature in the drainage thalweg, capable of safely passing the 2-year, 24-hour design runoff event. A flood plain will be constructed parallel to the active channel capable of containing a 100-year, flood peak.

(c) Seedbed preparation is best accomplished by the use of treatment A (TABLE F) in the western portion of the old waste pile and treatment C on the eastern portion to conform with waste characteristics of the former piles. It is important to rip the entire area to relieve soil compaction prior to seedbed preparation.

(d) The Grassed Waterway (see TABLE H) seed mixture should be used at this site.

Constructions costs are $425,000 to $450,000.

Berten Mine

Mine features are well-defined and could be reclaimed simply. Recommendations are presented below.

(a) Both portals should be blasted shut using conventional explosives.

(b) The second adit, which has a partially caved portal, is well-defined by subsidence and should be completely collapsed by blasting. Resulting voids can be filled with dump material capped by two feet of on-site soils.

(c) Dump material or slack should be compacted to near zero air void condition.

(d) The tipple structure can be demolished, stockpiled, and burned or buried on site. The scale shack and building ruins should be demolished and buried.

(e) Seedbed treatment A (TABLE F) is applicable at this site.

(f) The Grassed Waterway (see TABLE H) seed mixture should be

used at this site.

The shale rich waste area is not big and is not apparently a source of salts or toxic element contamination. No reclamation of this area is recommended.

Costs are estimated at $20,000 to $25,000.

Musselshell Mine

Reclamation at the Musselshell Mine is minor. The headframe should be removed. Any mechanical alteration of the surface would create a disturbance greater than exists now. No action is recommended.

Cost estimate is $3,000 to $4,000. These costs include cleanup and burial of wastes and regrading.

Antelope Mine

The Antelope Mine requires closing an open portal and adit and demolishing the tipple. The open portal can be collapsed by blasting or equipment and subsequently backfilled. Demolition of the collapsing tipple and piling of rubble is recommended.

Additional reclamation at the site includes cleanup, demolition of other structures, and regrading. The Upland Grassland Alternative A (see TABLE H) seed mixture should be used here. Seedbed treament C presented in TABLE F should be applied to all the areas needing revegetation.

Costs are estimated at $3,500 to $5,000 for limited reclamation, to clost the portal and collect and pile the rubble.

Johnies Mine

The Johnies Mine consists of a caved adit, a caved air shaft, and a

partially open adit. Although the site is remote, recommendations are presented below.

(a) The portal should be collapsed by blasting. The opening should then be backfilled and covered with onsite wastes.

(b) All trenches and shafts should be filled with onsite soils and graded to provide positive drainage. Fill should be mounded to six inches above adjacent grade.

(c) The tipple should be demolished and burned or buried. The rest of the old structure and ruins, including debris and trash, excepting the large shop building, should be demolished and buried.

(d) The mine wastes and disturbed areas should be leveled, contoured, and revegetated using the Upland Grassland (see TABLE H) seed mixture. Prior to reseeding, all disturbed areas will require the seedbed treatment A presented in TABLE F.

Reclamation can be completed using conventional construction equipment and methods; costs are estimated at $18,000 to $20,000.

Oxbow Mine

The Oxbow Mine is a remote site, but the landowner wishes to utilize the open adit for livestock shelter and to cover but not fill the air shaft. Therefore, we present the following recommendations.

(a) All subsidence features should be backfilled with onsite soils, mounded to six inches above adjacent grade.

(b) The air shaft should be capped with a concrete cover with locking frame and hatch to allow landowner access.

(c) No reshaping or revegetation is recommended. The owner wants the large pile of slack and mine waste left for his future use.

(d) The adit to be used as a livestock shelter should be plugged 100 feet back from the portal with a shorcrete bulkhead.

(e) Concrete remnants removed and buried.

Costs are estimated to be $8,000 to $10,000.

Jeffries 18 Mine

Two adits should be sealed with on-site materials and covered over with on-site waste and topped with suitable material. The existing structure should be removed and the site cleaned. Structures and foundations should be demolished and buried. Slack and waste piles located on each side of the river should be leveled and revegetated.

The Grassed Waterway (TABLE H) seed mixture will be very effective in providing a quick stable cover on the mine site and adjacent waste pile. Reducing the slope to a 10 to 20 percent grade or creating terraces will assist in reducing runoff. Use of the seedbed treatment C (TABLE F) is recommended.

Soils of the adjacent floodplain are sandy and contain little organic matter so would be a marginal source of borrow material. The texture of the regraded surface could determine the usefulness of local borrow material. If coarse sands dominate the fines and gravels make up more than 35 percent of the regraded surface, about a half foot of floodplain materials could make a better material for seeding into. Additional organic mulch is necessary if this sandy material is used.

Costs are estimated at $14,000 to $18,000.

Number 4 Mine

The Number 4 workings are readily accessible from a county road about five miles east of Roundup. A residence is about one-quarter mile away. Recommendations are presented below.

(a) The portal should be sealed with shotcrete.

(b) The access trench and air shaft should be backfilled with on-site soils and the shaft covered with a concrete cap. Removal of the block structure covering the shaft is also required.

(c) Tipple should be demolished and burned or buried, and foundations, structures, and debris should be demolished and buried.

(d) Few problems are present particularly if the wastes are buried or used as fill in the shaft. The seedbed Treatment A (TABLE F) is suggested before seeding. No liming is necessary.

(f) The Upland Grassland Alternative A (see TABLE H) seed mixture should be used at this site.

Cost is estimated at $10,000 to $12,000.

Carlson 33 Mine

This mine is located on the Gebhardt Ranch about five miles south of Gage. The workings have been fenced and present no immediate hazard. However, for ranking purposes, we present the following recommendations.

(a) The open adit should be closed by blasting.

(b) Access trenches and shafts should be backfilled with on-site soils graded to provide positive drainage.

(c) The portal should be sealed with on-site materials. The plug should extend a minimum of five feet into the adit.

(d) Remaining slack and waste piles should be leveled, amended using Treatment A (TABLE F) and revegetated with the Upland Grassland Alternative A (TABLE H) seed mixture. If the pile were spread to approximately six inches and disked into the soil, the fire hazard and poor growing conditions could both be handled. Work can be completed with construction equipment.

Estimated cost is $8,000 to $10,000.

Howard Mine

This mine consists of a single open adit and is not readily accessible

except by jeep trail. Livestock use the adit for shelter. The mine presents no clear danger. For ranking purposes, we present the following recommendation.

Backfill and cover open portal with material available on-site and regrade slope using construction equipment. The Upland Grassland Alternative A (see TABLE H) seed mixture should be applied to all recontoured areas.

Cost is estimated at $2,500 to $3,000.

RANKING

The overriding consideration in reclamation of abandoned mines in the Bull Mountain Coal Field was impacts which pose potential health and safety hazards. To a lesser extent, additional consideration was given to impacts to local land uses.

Health and safety hazards were evaluated and ranked depending on severity of hazard, immediate danger to health and/or safety, location and accessibility, and proximity to residences or populated areas. Each category was assigned a value from one to five, with one being lowest impact and five being highest. The relative ranking was accumulated for each category to achieve a value of from 1 to 5. Land use impacts were ranked by significance of loss with each site obtaining a relative score between one and five. Taken together, this ranking system identifies the severity of each mine site relative to the criteria applied. Total scores for each site could range between 5 and 25. Since the majority of elements used in the impact ranking were health and safety related, a built-in weighing took place and the emphasis on these impacts was reflected in the total score for each mine site. The sites were evaluated based on the following evaluation totals:

Total Score:	RECOMMENDATION:
0-6	Impacts are not sufficient to require immediate abatement. Reclamation may be deferred pending availability of funds.
7-11	Abatement is indicated and should be completed as soon as practical. Imminent threat to life and/or property is not great.
12-16	Significant hazards exist and pose a threat to health and safety. Immediate steps should be taken toward abatement of at least the high hazard items.

Total Score:	RECOMMENDATION:
17-25	Extremely dangerous conditions exist or life threatening potential is imminent. Immediate steps should be taken to abate or correct the condition regardless of cost.

The tabulation of relative impacts is presented in TABLE J.

TABLE J. Evaluation of health and safety hazards.

Mine	Severity of Hazards	Potential for Immediate Diaster	Accessibility and Location	Proximity to Residences and Population	Land Use Impact	Relative Total Severity
Nelson	4	5	4	1	1	15
Keene 26	4	5	3	2	1	15
Carpenter	2	3	2	1	1	9
Nies	5	5	4	3	2	19
Square Deal	2	1	3	3	1	10
Johnson	5	5	4	4	3	21
Keene 28	5	4	3	3	1	16
Jeffries No. 4	4	5	1	1	1	12
Cooper	2	2	3	4	1	12
Western	5	4	1	1	2	13
Roundup	5	5	3	4	4	21
Berten	4	4	1	1	1	11
Musselshell	1	2	1	1	1	6
Antelope	5	4	1	1	1	12
Johnies	5	5	4	3	1	18
Section 16	5	5	3	4	1	18
Oxbow	4	5	3	2	1	15
Jeffries	5	5	2	4	1	17
Roundup No. 4	5	4	4	3	1	17
Carlson	4	3	1	1	1	10
Howard	3	2	1	1	1	8
Republic No. 3	3	5	4	4	4	20

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APPENDIX A

SOILS

Table 1

Unsuitability Criteria for Soil or Soil Substitutes

Parameter	Suspect Level[1]		
pH		< 5.5	
		> 8.5	
Conductivity (mmhos/cm)	Lift 1	> 4.0	
	Lift 2	> 4.0-8.0[2]	
Saturation percentage		> 85%	
		< 25%	
Sodium adsorption ratio[3]		> 11.0	cl (≤ 35% c), scl, sil (≥ 20% c, ≥ 15% s), l (≥ 20% c)
		> 14.0	sl,l (< 20% c), sil (< 20% c, ≥ 15% s)
Exchangeable sodium percentage[3]		> 15.0	cl (≤ 35% c), scl, sil (≥ 20% c, ≥ 15% s), l (≥ 20% c)
		> 18.0	sl, l (< 20% c), sil (< 20% c, ≥ 15% s)
Boron		> 5 ppm	
Selenium		> 0.1 ppm	
Textural Class[3]		c, sc, sic, sicl (> 35% c, < 15% s), sil (< 15% s), si, ls, s	
Coarse fragments	Lift 1	> 20%[4]	
	Lift 2	> 35%[4]	

---

[1] The suspect levels are to be used as a guide in evaluating the suitability of a soil material for reclamation. An evaluation should take into account the 'total system'. Interactive parameters may either nullify or verify the significance of a potential problem.

[2] The actual maximum acceptable salt level will depend on the plant species proposed in the revegetation plan and the potential for upward salt movement.

[3] See Figure 1.

[4] These values may vary depending upon the plant species proposed for revegetation in specific locations (e.g. a soil with a very high coarse fragment content throughout its profile may be completely salvaged if used for certain shrub or tree plantings).

Table 2

Unsuitability Criteria for Overburden and Regraded Spoils

Parameter	Suspect Level[1]	
pH	< 5.5 > 8.5	
Conductivity (mmhos/cm)	> 4.0-8.0[2]	
Saturation percentage	< 25% > 85%	
Exchangeable sodium percentage[3]	> 15.0	cl (≤ 35% c), scl, sil (≥ 20% c, ≥ 15% s), l (≥ 20% c)
	> 18.0	sl, l (< 20% c), sil (< 20% c, ≥ 15% s)
Boron	> 5 ppm	
Molybdenum	> 0.5-1.0 ppm[4]	
Selenium	> 0.1 ppm	
Textural class[3]	c, sc, sic, sicl (> 35% c, < 15% s), sil (< 15% s), si, ls, s	

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[1] See footnote 1 in Appendix A

[2] See footnote 2 in Appendix A

[3] See Figure 2.

[4] The actual maximum acceptable molybdenum level will depend upon the plant species proposed in the revegetation plan and their potential for molybdenum accumulation.

Table 3

Sample Locations

Sample #	Mine Name	Depth of Sample (inches)	Represents:
1	Nelson	0-12	Gray shales, no coal
2	Western	0-12	Coal pile, no shale
3	Republic No. 3	0-12	High coal content
4	" " "	12-24	" " "
5	" " "	24-36	" " "
6	" " "	36-48	" " "
7	" " "	0-12	Mod. high coal content
8	" " "	12-24	" " " "
9	" " "	24-36	" " " "
10	" " "	36-48	" " " "
11	" " "	0-12	Low coal content-gray shale
12	" " "	12-24	" " " " "
13	" " "	24-36	" " " " "
14	" " "	36-48	" " " " "
15	Williams	0-12	Alluvial topsoil-alfalfa meadow
16	"	24-36	Alluvial substrate- " "
17	"	0-12	Alluvial topsoil-native range
18	"	0-12	Alluvial-heavy subsidence zone
19	"	12-24	" " " "
20	"	24-48	" " " "
21	"	48-60	" " " "
22	Keene East	0-1	Compact shale-rich waste pile
23	" "	1-5	" " " " "
24	" "	6-12	" " " " "
25	" "	12-24	" " " " "
26	" "	0-12	Blown coal pile
27	Oxbow	0-12	Black wastes-rich in coal
28	"	0-12	Red wastes-burned coal

Table 3, concluded

Sample Locations

Sample #	Mine Name	Depth of Sample (inches)	Represents:
29	Oxbow	0-12	Sandstone wastes-no coal
30	Keene West	0-12	Coarse grained coal-no plants
31	" "	0-12	Fine graned coal-plant cover
32	" "	0-12	Sandstone and shale wastes

Table 4

Physical Properties of Materials Sampled at the Bull Mountains Coal Field

Sample	Mechanical Analysis				Water Holding Capacity			
#	Sand	Silt	Clay	Very Fine Sand %	Saturation	1/3 bar	15 bar	Plant Available
1	21.1	52.7	26.2	7.7	52.4	-	-	-
2	79.3	14.5	6.2	7.5	52.3	-	-	-
3	60.2	23.6	16.2	34.6	45.8	21.5	14.6	6.9
4	62.0	23.6	14.4	21.1	47.9	22.7	15.2	7.5
5	59.3	27.2	13.5	19.4	46.0	21.0	14.4	6.6
6	60.2	24.5	15.3	25.2	49.0	24.7	16.0	8.7
7	44.7	32.8	22.5	22.6	50.2	-	-	-
8	52.0	30.0	18.0	22.3	53.4	-	-	-
9	58.4	26.3	15.3	22.1	46.9	-	-	-
10	69.3	19.1	11.6	24.2	48.1	-	-	-
11	36.5	41.9	21.6	17.0	43.1	18.2	8.6	9.6
12	32.0	43.6	24.4	16.4	49.1	19.8	7.9	12.9
13	53.8	33.7	12.5	16.8	41.4	19.0	4.9	14.1
14	56.5	31.0	12.5	17.5	44.5	28.4	8.4	20.2
15	-	-	-	-	-	21.3	10.7	10.6
16	-	-	-	-	-	14.6	6.3	8.3
17	-	-	-	-	-	14.0	7.9	6.1
18	-	-	-	-	-	22.6	11.2	11.4
19	-	-	-	-	-	31.8	12.1	19.7

Table 4, concluded

Physical Properties of Materials Sampled at the Bull Mountains Coal Field

Sample	Mechanical Analysis				Water Holding Capacity			
#	Sand	Silt	Clay	Very Fine Sand %	Saturation	1/3 bar	15 bar	Plant Available
20	-	-	-	-	-	23.3	6.8	16.5
21	-	-	-	-	-	7.3	3.7	3.5
22	45.1	30.9	24.0	1.4	45.2	-	-	-
23	53.3	23.6	23.1	7.9	54.1	-	-	-
24	51.5	23.6	24.9	11.0	56.3	-	-	-
25	56.0	21.8	22.2	11.4	57.6	-	-	-
26	82.4	13.1	4.5	4.8	77.8	-	-	-
27	67.8	27.3	4.9	9.1	34.3	-	-	-
28	72.4	25.4	2.2	4.2	37.7	-	-	-
29	74.2	21.8	4.0	7.2	29.1	-	-	-
30	86.0	10.4	3.6	5.7	59.3	-	-	-
31	83.3	14.0	2.7	2.1	75.5	-	-	-
32	41.5	45.4	13.1	30.9	36.5	-	-	-

Table 5

Chemical Properties of Materials Sampled at the Bull Mountains Coal Field

Sample #	pH	Electrical Conductivity (mmhos/cm)	---- Soluble Cations --- Ca	Mg	Na	SAR	Organic Matter (%)	N	P	K	B	Mo
			------- (meq/l)	--------				----------------	(ppm)	----------------		
1	6.7	3.63	25.7	21.0	5.9	1.2	8.9	12.2	0.6	125	-	-
2	4.3	3.23	27.1	18.6	1.8	0.4	20.8	6.4	1.0	27	-	-
3	5.5	1.41	9.5	7.0	0.6	0.2	16.2	5.0	1.7	104	0.62	0.51
4	4.9	2.22	28.1	16.3	1.5	0.3	18.5	6.4	1.6	83	0.69	0.43
5	6.1	3.08	27.1	21.4	1.6	0.3	18.4	5.4	1.4	95	0.82	0.54
6	5.4	2.93	27.2	20.5	1.8	0.3	19.3	7.1	1.3	79	0.81	0.57
7	4.9	2.22	27.6	15.8	1.3	0.3	14.7	6.1	0.9	126	-	-
8	4.7	3.33	26.6	23.4	2.4	0.5	14.7	6.0	1.0	99	-	-
9	6.2	3.33	27.8	29.1	5.8	1.1	15.1	5.4	1.0	94	-	-
10	5.9	4.29	25.3	29.8	9.4	1.8	20.1	5.3	0.3	108	-	-
11	7.7	0.61	2.89	1.8	6.4	4.2	10.4	7.3	0.5	163	0.66	0.61
12	7.4	4.34	22.4	14.8	20.6	4.8	12.1	6.8	0.4	141	0.52	0.42
13	7.3	6.06	20.8	13.6	40.1	9.7	9.8	9.9	0.4	122	0.61	3.16
14	7.2	5.55	26.1	16.8	41.2	8.9	14.7	14.8	0.4	139	0.72	0.82
15	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	15.5	5.5	42	-	-
17	-	-	-	-	-	-	-	1.5	1.6	17	-	-
18	-	-	-	-	-	-	-	1.0	4.2	237	-	-
19	-	-	-	-	-	-	-	1.0	1.8	99	-	-

Table 5, concluded

Chemical Properties of Materials Sampled at the Bull Mountains Coal Field

Sample	pH	Electrical	---- Soluble Cations ---			SAR	Organic	N	P	K	B	Mo
#		Conductivity	Ca	Mg	Na		Matter	---------------- (ppm) -----------------				
		(mmhos/cm)	------- (meq/l) --------				(%)					
20	-	-	-	-	-	-	-	1.0	5.6	28	-	-
21	-	-	-	-	-	-	-	2.0	1.3	9	-	-
22	2.9	12.2	30.3	26.8	1.6	0.1	20.7	6.7	0.8	23	1.35	1.07
23	2.9	5.6	25.1	52.1	1.1	0.2	20.5	6.4	0.7	22	1.02	0.81
24	2.9	7.9	26.3	10.3	1.7	0.2	19.3	5.2	0.3	36	3.09	0.86
25	2.8	8.3	23.7	10.9	1.7	0.2	21.6	6.4	0.4	21	2.79	0.95
26	3.6	3.3	16.2	17.7	0.4	0.1	57.4	25.0	2.4	509	-	-
27	4.3	3.2	26.0	13.1	1.9	0.4	6.0	18.3	5.9	493	-	-
28	7.6	4.1	27.5	25.3	6.8	1.3	0.0	1.3	7.1	144	-	-
29	7.2	4.0	29.2	19.0	6.8	1.4	0.2	13.5	1.3	554	-	-
30	4.4	2.5	25.4	8.5	0.4	0.1	55.0	-	-	-	-	-
31	5.7	0.9	3.2	2.7	1.3	0.8	52.7	-	-	-	-	-
32	7.7	0.5	1.5	1.6	0.7	0.6	3.5	-	-	-	-	-

APPENDIX B

WATER QUALITY ANALYSES

ENERGY
LABORATORIES

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

Lab. No. 83-3997

To Dave Stiller and Associates Date 6-8-83 CB

Address Steamboat Block 616 Helena Avenue Helena, MT 59601

WATER ANALYSIS REPORT

Keene 26 Mine
Sampled 5-25-83 @ 16:15
Sample Received 5-26-83

CONSTITUENTS	MILLIGRAMS PER LITER
Potassium	10
Sodium	167
Calcium	333
Magnesium	387
Sulfate	2,370
Chloride	14
Carbonate	0
Bicarbonate	375
Nitrate-N	<0.05
Total Iron	10.9
Total Solids (Calculated)	3,460
Total Hardness As $CaCO_3$	2,430
Total Manganese	1.74

Specific Conductance @ 25° C 3,800 Micromhos/cm
pH 6.7

Total Aluminum	<0.1

ENERGY
LABORATORIES

ENERGY LABORATORIES, INC.
P.O. BOX 30916 · 1107 SOUTH BROADWAY · BILLINGS, MT 59107-0916 · PHONE (406) 252-6325

Lab. No. 83-3996

To Dave Stiller and Associates

Date 6-8-83 CB

Address Steamboat Block 616 Helena Avenue Helena, MT 59601

WATER ANALYSIS REPORT

Carpenter Creek Above Mine
Sampled 5-25-83 @ 16:00
Sample Received 5-26-83

CONSTITUENTS	MILLIGRAMS PER LITER
Potassium	7
Sodium	230
Calcium	68
Magnesium	163
Sulfate	769
Chloride	16
Carbonate	0
Bicarbonate	603
Nitrate-N	<0.05
Total Iron	0.13
Total Solids (Calculated)	1,550
Total Hardness As $CaCC_3$	841
Total Manganese	0.03
Specific Conductance @ 25° C	2,150 Micromhos/cm
pH	8.2
Total Aluminum	<0.1

ENERGY LABORATORIES

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

Lab. No. 83-3995

To Dave Stiller and Associates

Date 6-8-83 CB

Address Steamboat Block 616 Helena Ave. Helena, MT 59601

WATER ANALYSIS REPORT

Carpenter Creek Below Mine
Sampled 5-25-83 @ 15:10
Sample Received 5-26-83

CONSTITUENTS	MILLIGRAMS PER LITER
Potassium	7
Sodium	232
Calcium	97
Magnesium	180
Sulfate	907
Chloride	18
Carbonate	0
Bicarbonate	635
Nitrate-N	<0.05
Total Iron	0.12
Total Solids (Calculated)	1,760
Total Hardness As $CaCO_3$	983
Total Manganese	0.07
Specific Conductance @ 25° C 2,330	Micromhos/cm
pH 8.0	
Total Aluminum	<0.01

APPENDIX C

DRILL LOG DATA

ULTANTS, INC.

CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: Joergen Pilz
REMARKS:

HOLE NO. TB-1
SHEET 1 OF 1
LOCATION Next to sawmill by sawdust pile
ELEVATION: TOP OF HOLE N.A.
GROUNDWATER 15'
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack, dry, angular, oxidized, very loose to loose brown, 80°F										
			SPT	2	-							
			SH	-	15.0	103						
11.5		Sand - SM - fine sand & silt, moist cohesionless, angular, to subrounded interbedded w/sand zones 2-3" thick which exhibit seepage and medium plast. silty clay.										
16.5			SPT	7	-							
		Seepage zones begin at 15.0". Bot. in native material.										

ULTANTS, INC.

CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field

JOB NO.: G169-1

DRILL TYPE: SOIL H.S. Auger

ROCK

DRILLED BY: D. Wells

LOGGED BY: J. Pilz

REMARKS:

HOLE NO. TB-2

SHEET 1 OF 1

LOCATION

ELEVATION: TOP OF HOLE N.A.

GROUNDWATER

DATE: HOLE STARTED 8-5-83

HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - soft/loose, angular, dry, brown to yellow, osidation, cool, black 80°F										
			SH	-	-	73	-	-	-	-	-	-
			SPT	3	-	-	-	-				
9.0		Silty Sand - MS - fine sand & silt, moist, green to tan, interbedded with soft silty clay of low plasticity.	SPT	2	-	-						
11.5		Bot. in native material.										

ULTANTS, INC.

CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G-169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-3
SHEET 1 OF 1
LOCATION See attached map
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - soft/loose, yellow, sulphur stains, dry, fine grained, black. 84°F.	SPT	2	-	-						
5.0		Massive Beds of Coal slack, very few fine particles, dense, fractured										
			SPT	12"/R	-	-						
14.0		Sandstone - fissile, fine sand & silt minor clay, hard w/weathered zones, moist, subrounded, yellow to green.	SPT	6"/R	-	-						
16.5												

LTANTS, INC.

CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-4
SHEET 1 OF 1
LOCATION See attached map
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - dry, loose, 80% - 200 sieve (dust), hard layers of ash grey shale zones which are moist, slightly plastic. 80°F.										
			SPT	8	-	-						
			SPT	5	-	-						
			SPT	11	-	-						
17.0		Silty Sandstone - SM, moist, low plasticity, yellow, 30% clay										
20.0												

ULTANTS, INC.

CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-5
SHEET 1 OF 1
LOCATION see attached map
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - dry, cool, grey, hard shale interbeds										
			SPT	10	-	-						
6.0 6.5		Silty Sandstone - moist, fine sand, silty, low plasticity, wood fragments at top										

ULTANTS, INC.

CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-6
SHEET 1 OF 1
LOCATION see attached map
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - black, loose coal and grey, hard, shale beds										
			SH	-	-	86						
			SPT	7	-	-						
10												
		Thin layer of ash grey shale, very hard, minor plasticity	SPT	10	-	-						
			SPT	10	-	-						
20												
			SPT	7	-	-						
25.5 26.5		Silty Sand - SM - moist, medium to fine sand, silty, angular to sub-rounded, yellow	SPT	4	-	-						

ULTANTS, INC.

CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-7
SHEET 1 OF 1
LOCATION see attached map
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - interbedded black coal and grey shale, dry, loose, 60% - 200 mesh										
			SPT	6	-	-						
10												
			SPT	3	-	-						
		Temp. - 105°F	SPT	5	-	-						
18.0		Silty Sand - SM - fine sand, silt, moist, loose	SPT	3	-	-						
20.0												

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CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-8
SHEET 1 OF 1
LOCATION At saw mill site
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - dry, loose, angular										
			SPT	2	-	-						
6.0		Clayey Silt (ML-CL) - soft, medium plastic, moist, low, strength, green to brown,										

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CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-9
SHEET 1 OF 1
LOCATION see attached map
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Silty Sand fill - SM - dry, fine sand, non-plastic, angular, yellow-green.										
4.0		Coal Slack - loose, angular blocks & fragments, dry, black, cool.										
9.0 10		Silty Sand - SM - loose to medium dense, native material, yellow.										
		Note: Wind-deposited coal dust covers the area. Most of coal slack has been mucked out near TB-9 through TB-11.										

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CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-10
SHEET 1 OF 1
LOCATION see attached map
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-5-83
HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Wind-blown Coal Dust - 90% - 200 mesh, loose, dry										
1.0		Silty Sand - SM - moist, weathered sandstone, fine sand, silt, non-plastic, angular to subrounded, yellow-green										
10.0												

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CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field

JOB NO.: G169-1

DRILL TYPE: SOIL H.S. Auger

ROCK

DRILLED BY: D. Wells

LOGGED BY: J. Pilz

REMARKS:

HOLE NO. TB-11

SHEET 1 OF 1

LOCATION see attached map

ELEVATION: TOP OF HOLE

GROUNDWATER None

DATE: HOLE STARTED 8-5-83

HOLE COMPLETED 8-5-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - loose, angular, pea gravel size chips, windblown										
5.0		Silty Sand - SM - loose, moist, fine sand, silty, non-plastic, subrounded, yellow-green										
10.0												

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CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field	HOLE NO. TB-12
JOB NO.: G169-1	SHEET 1 OF 1
DRILL TYPE: SOIL H.S. Auger	LOCATION see attached map
ROCK	ELEVATION: TOP OF HOLE
DRILLED BY: D. Wells	GROUNDWATER None
LOGGED BY: J. Pilz	DATE: HOLE STARTED 8-6-83
REMARKS:	HOLE COMPLETED 8-6-83

DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - dry, loose, angular, 70% - 200 mesh, increasing fragment size w/depth; interbedded w/ash grey shale beds. Moist at 10.0 to 15.0 ft.	SPT	4	-	-						
10			SPT	2	-	-						
			SPT	3	-	-						
19.0		Silty Sand - SM - fine sand, silt, moist, non-plastic, green-yellow	SPT	3	-	-						
21.5												

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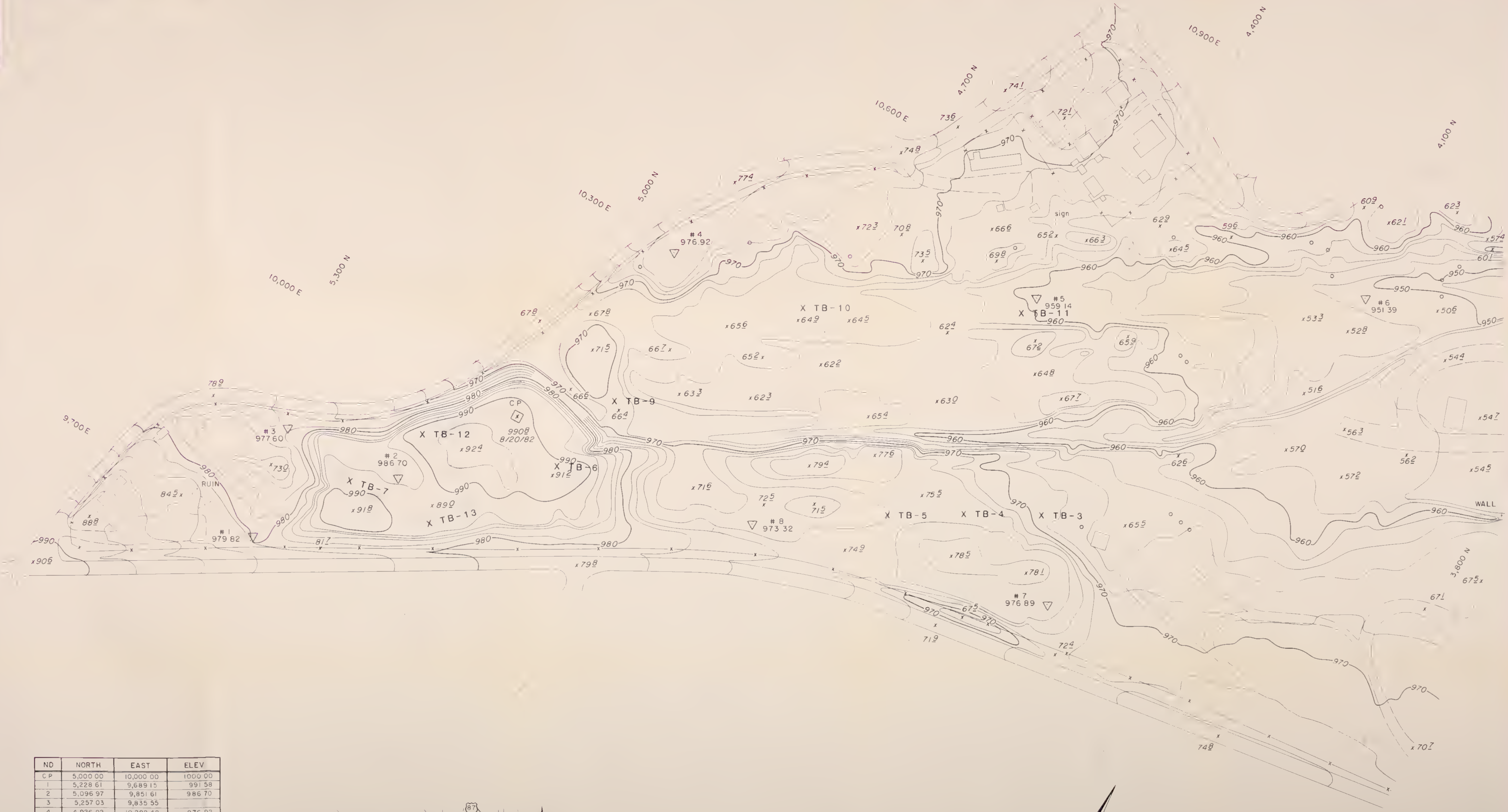
CONSULTING GEOTECHNICAL ENGINEERS

LOG OF EXPLORATION HOLE

PROJECT: AML Bull Mountain Coal Field
JOB NO.: G169-1
DRILL TYPE: SOIL H.S. Auger
ROCK
DRILLED BY: D. Wells
LOGGED BY: J. Pilz
REMARKS:

HOLE NO. TB-13
SHEET 1 OF 1
LOCATION see attached map
ELEVATION: TOP OF HOLE
GROUNDWATER None
DATE: HOLE STARTED 8-6-83
HOLE COMPLETED 8-6-83

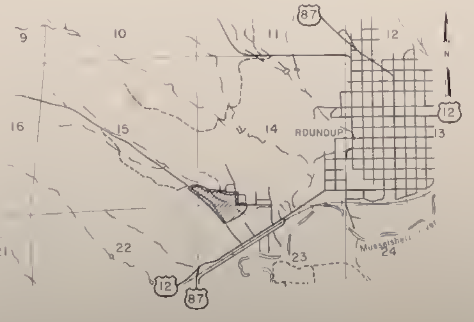
DEPTH (Feet)	LEGEND	CLASSIFICATION AND DESCRIPTION	SAMPLE SYMBOL	S.P.T. (N) (BLOWS/FT.)	MOISTURE CONTENT (%)	IN-PLACE DRY DENSITY (pcf)	L.L. %	P.I. %	GRAVEL %	SAND %	SILT %	CLAY %
0		Coal Slack - loose, dry, w/shale beds.										
15.0		Silty Sand - SM - loose, moist, yellow-green										
20.0												



ND	NORTH	EAST	ELEV
C P	5,000 00	10,000 00	1000 00
1	5,228 61	9,689 15	991 58
2	5,096 97	9,851 61	986 70
3	5,257 03	9,835 55	
4	4,926 92	10,292 42	976 92
5	4,478 64	10,479 29	959 14
6	4,089 83	10,704 00	951 39
7	4,261 25	10,132 59	976 89
8	4,659 71	10,031 30	973 32

Horizontal Grid North Based On Azimuth Bearing 306°19'57", C.P. To Point No. 1. Vertical Datum Based On Assumed Elevation 1000.00' At C.P. Ground Control Surveys Conducted June 13, 1980 By Montana Department of State Lands.

Topography Prepared From Hasselblad Camera, 50 MM. Distagon Lense, Aerial Photography, 1"=800', July 9, 1980, With Lense Correction Applied. This Topography Is Of Reconnaissance Class And Has Not Been Field Checked. Associated Surveys, Inc., Billings, Montana.



LEGEND

PAVED ROAD
IMPROVED ROAD
TRAIL
BRIDGE
CATTLE GUARD
CULVERT
FENCE
RAILROAD
POWER POLE
TREES
DRAINAGE
POND
SWAMP
INDEX CONTOUR
INTERMEDIATE CONTOUR
DEPRESSION CONTOUR
BUILDING
DEPTH OF SUBSIDENCE

CONTOUR INTERVAL 2'

0 30 60 120 180

GRAPHIC SCALE IN FEET
ORIGINAL SCALE 1"=60'

STATE OF MONTANA
DEPT. OF STATE LANDS
RECLAMATION DIVISION

DRILL LOG HOLES

REPUBLIC #3 MINE

S.E./4, S.E./4 SEC. 15
T8N, R25E
MUSSELSHELL COUNTY, MONTANA

ASSOCIATED SURVEYS INC.
land & aerial
BILLINGS, MONTANA